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5e. TASK NUMBER

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14. ABSTRACT
For all team activities, whether it be sports teams or military units, winning is the ultimate goal. To truly achieve team success, the team should be able to complete a task with the least amount of moves or use the least amount of energy without sacrificing quality.

In this study, we are trying to determine the factors that contribute the most to successful teams under stressful conditions. We hypothesize that by measuring individual biological responses, such as heart rate, breathing rate

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Jonathan Boyd
UU	UU	UU	UU		19b. TELEPHONE NUMBER 304-615-9627

Report Title

Using Estimations of Entropy to Optimize Complex Human Dynamic Networks under Stress Final Report

ABSTRACT

For all team activities, whether it be sports teams or military units, winning is the ultimate goal. To truly achieve team success, the team should be able to complete a task with the least amount of moves or use the least amount of energy without sacrificing quality.

In this study, we are trying to determine the factors that contribute the most to successful teams under stressful conditions. We hypothesize that by measuring individual biological responses, such as heart rate, breathing rate, posture, temperature, and saliva/blood components, during various physically and mentally stressful exercises, we will be able to determine the factors that drive overall team success and assemble more effective teams using these factors. Sixteen WVU Air Force ROTC participants were selected, divided into four different teams of four individuals, their biological responses were monitored (some in real-time and some prior to and immediately following) in response to stressful teamwork exercises (mock hostage rescue). Individuals were outfitted with EEG, heart rate, breathing rate, estimated core temperature, sound, activity and posture monitors and tasked with finding the "hostage" and moving it to a safe location; to move the hostage required the assembly of a make-shift gurney from items hidden in an urban setting. These exercises were expected to simulate aspects of the types of stresses endured by U.S. Military Special Operations Forces and Hostage Rescue Teams of the Federal Bureau of Investigation.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
02/27/2014	3.00	Holly N. Currie, Julie A. Vrana, Alice A. Han, Giovanni Scardoni, Nate Boggs, Jonathan W. Boyd. An Approach to Investigate Intracellular Protein Network Responses, Chemical Research in Toxicology, (01 2014): 0. doi: 10.1021/tx400247g
10/01/2013	2.00	Julie A. Vrana, Nathan Boggs, Holly N. Currie, Jonathan Boyd. Amelioration of an undesired action of deguelin, Toxicon, (11 2013): 0. doi: 10.1016/j.toxicon.2013.07.028
10/01/2013	1.00	Jonathan Boyd, Julie A. Vrana, Holly N. Williams. In vitro approach to predict post-translational phosphorylation response to mixtures, Toxicology, (11 2012): 0. doi: 10.1016/j.tox.2012.10.010
TOTAL:	**3**	

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received	Paper

TOTAL:

Number of Manuscripts:

Books

Received	Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Julie Vrana	0.50	
Alice Han	0.50	
FTE Equivalent:	**1.00**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Jonathan Boyd	0.20	
Abel Rodriguez	0.10	
FTE Equivalent:	**0.30**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Constance Mitchel	0.01	
David Claypool	0.01	
FTE Equivalent:	**0.02**	
Total Number:	**2**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	1.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:.....	2.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:.....	2.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):.....	1.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:.....	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	1.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:.....	0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachement

Technology Transfer

Jonathan Boyd, West Virginia University
Abel Rodriguez, University of California, Santa Cruz
Using Estimations of Entropy to Optimize Complex Human Dynamic Networks under Stress
Final Report

Period Covered by the Report
June 15, 2012 through December 31, 2013

Date of Report: December 30, 2013

Project Title: Using Estimations of Entropy to Optimize Complex Human Dynamic Networks under Stress
Contract Number: W911NF-12-1-0165
Total Dollar Value: $482,835
Program Manager: Dr. Christian Macedonia, Defense Advanced Research Projects Agency

Submitted by:

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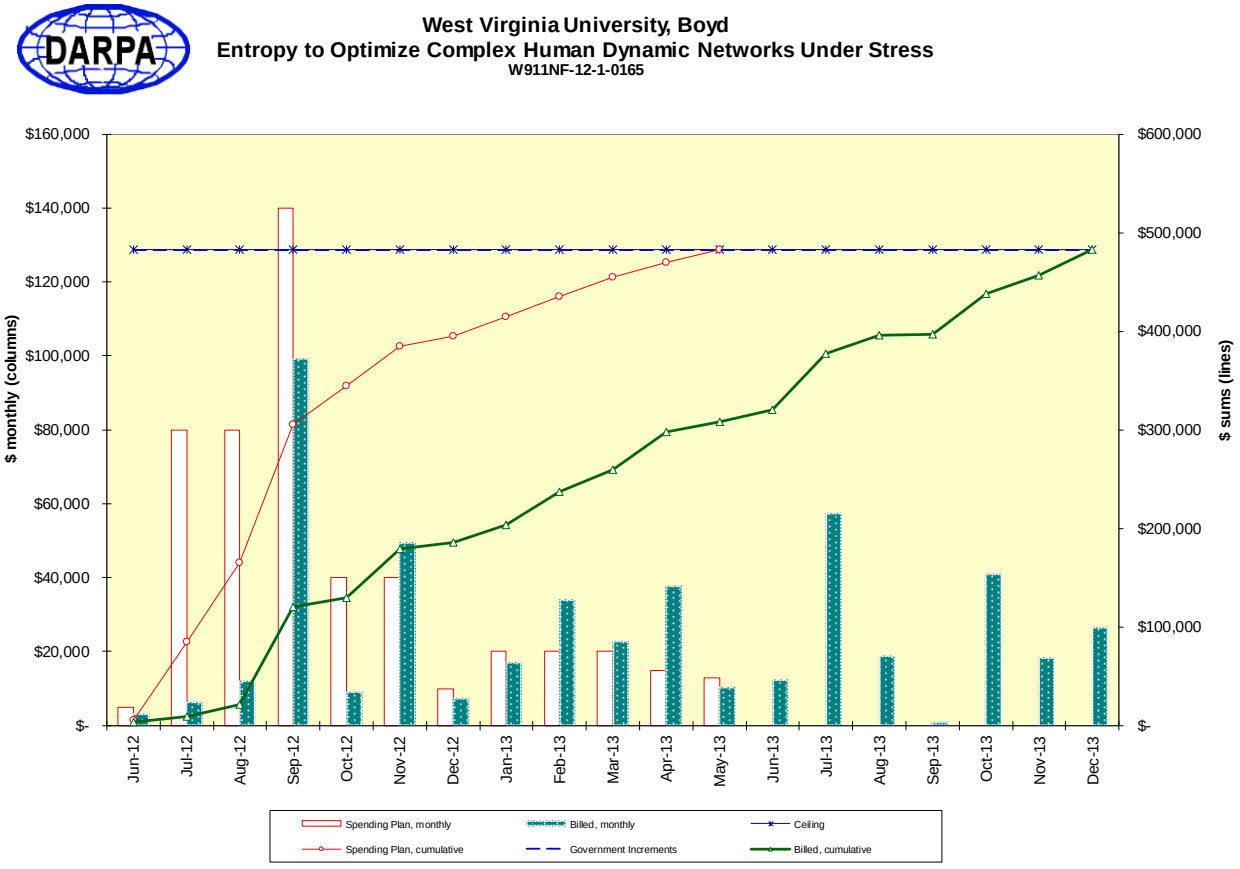
US Army Research Office
Durham, NC 27703

Technical Information – Financial Management

1. **Technical Progress / Monthly Expenditure Report (Please provide cumulative spending graph).**



Task 1. A written literature report that contains a comparison of biometric sensors that may be beneficial for understanding human response to stress. This will include sensors that are commercially available, academic only, and suggestions for future research.
Total cost: $17,285

Task 2. A written research report that contains preliminary data collection, processing and interpretation of data (from sensors selected in Task 1) that integrates biometric responses of humans under stressful conditions. Further, any computational programs or algorithms used for integration of the data will be included in this report.
Cost to date: $465,550

Total expenditures for the project - $482,835

2. Technical Progress / Highlights – Observations

Task 1.1. Literature survey.
This task is complete and was submitted to DARPA/DSO on August 31, 2012.

Task 1.2. Purchase and perform initial T&E; down-select sensors for use in Task 2
This task is complete and was included in our 3rd Quarterly Report.

Task 2.1. Optimize and trouble-shoot data collection for the selected biometric sensors.
This task is complete and was included in our 4th Quarterly Report.

Task 2.2. Define the required time to determine baseline.
This task is complete. We have investigated several baselines in order ensure that we have the data to improve the entropy estimations once we start optimizing our entropy calculations. We perform 3 different baselines for EEG:

- 5 minutes high engagement test (picking the correct shape in a sequence)
- 5 minutes low engagement test (clicking spacebar every time that a shape appears, ~ every 2 seconds)
- 5 minutes drowsiness (eyes closes, clicking spacebar every time a chime is heard, ~ every 2 seconds)

and 3 different baselines for all other measurements:

- 5 minutes mental stress (counting backwards from 1000 in intervals of 13)
- 5 minutes relaxation (individual is seated, we typically pull this baseline sample ~ 5 minutes after mental stress activity and ~ 5 minutes before we tell them we are drawing blood)
- 5 minutes of fear/pain stress (before and after venous blood draw)

At this point, our best results have come from data that has been normalized using times taken from 5 minutes mental stress and fear/pain stress. We have explored relaxation, engagement, and drowsiness, but not found any interesting results.

Task 2.3. Experimentally test biometric sensor suite with individuals and teams (with and without stress); optimize calculations of entropy.
EXPERIMENTAL: Currently, testing and analyses of individuals and teams is complete. Data has been collected and cataloged for all biomarkers (see previous Quarterly and Monthly Reports). Additionally, the figures of endogenous and exogenous biomarkers may be found below in Appendix I.

ENTROPY CALCULATIONS: Optimization of entropy model (for individuals and teams) with exogenous biomarkers is complete (see previous Quarterly and Monthly Reports). Additionally, entropy model data is presented in Appendix II below. It should be noted that any of the following calculations (or variants) can be calculated from any exogenous dataset. We chose to explore the following models using heart rate, breathing rate, temperature, activity and posture; additionally, we have performed these calculations with only heart rate, breathing rate and temperature as a means to remove any bias that might be present due to individual activity and posture when performing as a team.

For all subjects, data is downloaded from individual sensors and matched up according to their timestamps in 1 second intervals. We then export the real-time data starting at the first background task (counting backwards from 1000 in intervals of 13) and ending 10 minutes after crime scene house scenario 3 (CSH3) into GraphPad Prism (V5, Cary, NC).

For Shannon Entropy (nee Filter) Slope V1: The exported data from this time interval is then normalized over the time period using a probability distribution. By using probability distribution, the individual's smallest biomarker response (e.g., lowest heart rate, lowest breath rate, etc.) is set as zero and the highest biomarker response (individual's max heart rate, breath rate, etc.) is set to 1; therefore normalizing their individual responses. By including data from the beginning of background data collection through 10 minutes after CSH3 for data normalization, we should have captured their background/baseline exogenous biometric responses, i.e., minimum responses to mental and physical stress (relaxation period) and maximum responses to mental and physical stressors (e.g., count backwards, blood collection, crime scene house scenarios).

For Shannon Norm to Total: The exported data is then normalized over the entire time period for a global maximum value of each exogenous biomarker. We then normalize (divide) each of the exogenous responses (over time) by the respective maximum exogenous biomarker values from the entire experimental time period.

For Shannon Norm to Count: The exported data is then normalized over the entire time period by first isolating a short window of time (up to 180 seconds) during the mental stress activity of counting backwards from baseline exercises. We then normalize (divide) each of the exogenous responses by the respective maximum exogenous biomarker values from this period of mental stress.

For Shannon Norm to Blood: The exported data is then normalized over the entire time period by first isolating a short window of time (up to 180 seconds) during the fear/pain stress activity of having blood drawn during baseline exercises. We then normalize (divide) each of the exogenous responses by the respective maximum exogenous biomarker values from this period of fear/pain stress.

Normalization of the values allows (i.e., all values are on the same scale) for facile comparison between biomarkers directly, which ensures that one biomarker is not weighted more heavily than another.

For all Shannon Variants: After obtaining the normalized responses, we compute the Shannon entropy of each individual exogenous biomarker, $S(\lambda)$, over time (1 second intervals) by taking $S(\lambda) = p(\lambda) \log_2 p(\lambda)$ of each variable, λ.

For Shannon Entropy (nee Filter) Slope V1: Once each variable has its entropy computed over time, we take the Shannon total entropy, S_{Total}, where $S_{Total} = |-\Sigma S(\lambda)|$, across all variables at each second interval. Additionally, to show Shannon entropy accumulating over time, we take the integral of the sum of Shannon entropy, described as: $S_{Total'} = \int S_{Total}\, dt$.

Finally, to identify discrete changes in total Shannon entropy over time, we take the slope of the total Shannon entropy for a ten second window over time (note: this slope smoothing window may be decreased to a 2 second period if desired without changing the results).

Task 2.4. Write and deliver final report.
The information presented here is intended to serve as the Final Report.

Summary of subjects

	Subject	Gender	Age	Race	Weight (lb.)	Height (in.)	BMI	Body Fat %	Class Year	Rank
Team 1	4102	M	22	White	137.6	65	22.9	9.4	Senior	Cadet Captain
	4103	M	20	White	166.2	74	21.9	12.6	Junior	Cadet 1st Lt.
	4104	M	19	White	207.2	73	27.3	19.6	Freshman	Cadet 4th Class
	4110	M	18	White	155	70	22.2	15.7	Freshman	GMC, 100
Team 2	4105	M	19	White	121	67	19	8.2	Sophomore	C/3C
	4108	M	20	White	196.6	76	23.9	13.3	Sophomore	C/3C
	4112	M	19	White	191.4	75	23.3	17.5	Freshman	C/4C
	4113	M	18	White	200.2	74.5	25.3	21.4	Freshman	C/4C
Team 3	4106	M	19	White	152.2	68.5	22.8	14.4	Sophomore	C/3C
	4111	M	20	White	223.6	76.5	26.9	14.8	Sophomore	C/3C
	4115	M	19	White	183.6	74	23.5	16.6	Freshman	C/4C
	4116	M	19	White	153.8	68.5	23.1	12.5	Sophomore	C/3C
Team 4	4107	M	19	White	147.8	68.5	22.2	8.8	Freshman	C/4C
	4109	M	19	White	160.6	72.5	21.4	11.7	Freshman	C/4C
	4114	F	21	White	154.6	66	25	26.5	Junior	C/Colonel
	4117	M	21	White	213.8	72	29	21.6	Junior	C/Lt Col

Relevant Abbreviations

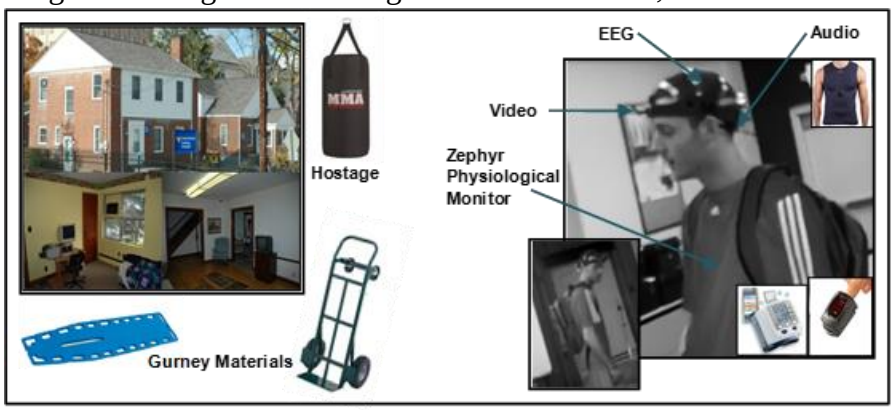
HR = heart rate,
BR = breathing rate,
POS = posture,
ACT = activity,
TEMP K -OR- T = temperature in Kelvin
Ipi = Individual plasma initial
Ipf = Individual plasma final
Tpi = Team plasma initial
Tpf = Team plasma final
Is1 = Individual saliva taken before CSH1 (crime scene house scenario 1)
Is2 = Individual saliva taken after CSH1, but before CSH2 (crime scene house scenario 2)
Is3 = Individual saliva taken after CSH2, but before CSH3 (crime scene house scenario 3)
Is4 = Individual saliva taken after CSH3
Ts1 = Team saliva taken before CSH1
Ts2 = Team saliva taken after CSH1, but before CSH2
Ts3 = Team saliva taken after CSH2, but before CSH3
Ts4 = Team saliva taken after CSH3

LAY SUMMARY

For all team activities, whether it be sports teams or military units, winning is the ultimate goal. To truly achieve team success, the team should be able to complete a task with the least amount of moves or use the least amount of energy without sacrificing quality.

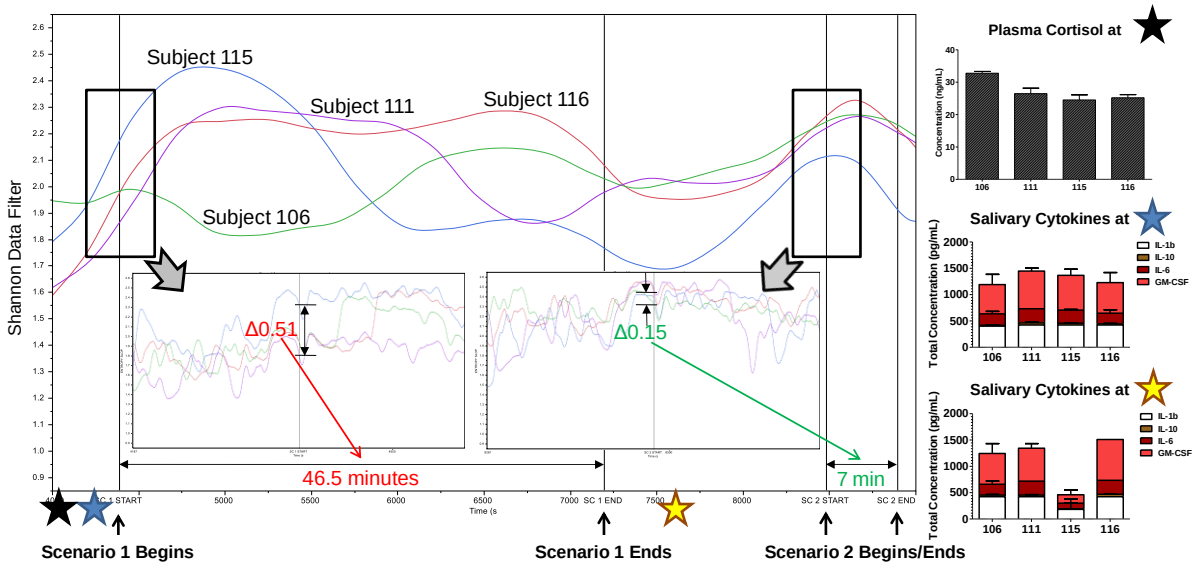
In this study, we are trying to determine what factors contribute the most to successful teams under stress. We hypothesize that by measuring individual biological responses, such as heart rate, breathing rate, posture, temperature, and saliva/blood components, during various physically and mentally stressful exercises, we will be able to determine the factors that drive overall team success and assemble more effective teams using these factors. Sixteen WVU Air

Force ROTC participants were selected, divided into four different teams of four individuals, their biological responses were monitored (some in real-time and some prior to and immediately following) to a stressful teamwork exercises (mock hostage rescue). Individuals were outfitted with EEG, heart rate, breathing rate, estimated core temperature, sound, activity and posture monitors and tasked with finding the "hostage" and moving it to a safe location; to move the hostage required the assembly of a make-shift gurney from items hidden in the house (see figure at right). These exercises were expected to simulate aspects of the types of stresses endured by U.S. Military Special Operations Forces and Hostage Rescue Teams of the Federal Bureau of Investigation.

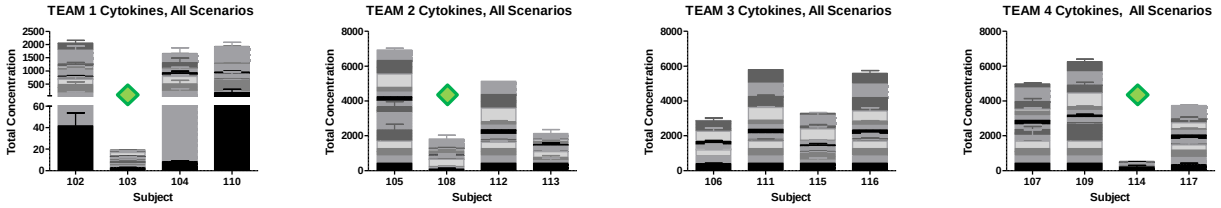


Overall mission recap: During the first mock hostage rescue mission, crime scene house 1 (CSH1), the subjects are told to complete the mission and they will be timed. The CSH1 mission familiarizes the subjects with the crime scene house and the task at hand. For the second hostage rescue mission (CSH2), the subjects are told to go as fast as they can, but still abide by the mission objectives and rules. In the third hostage rescue mission, the subjects are told that they will be timed again, however, 1 minute into the mission an air horn is blown and the mission director states, "Insurgents are returning! You have one minute left or you will be captured!" The second horn blows 1 minute after the first horn and the mission director yells, "FAIL! Assemble the hostage and come back to the garage [rendezvous point]." This mission acts as a failed mission and concludes with a "walk of shame". **Blood samples were taken before CSH1 and after CSH3; saliva samples were taken before CSH1, CSH2, CSH3 and after CSH3; blood pressure, temperature, and capillary O_2 were also measured before CSH1, CSH2, CSH3 and after CSH3.**

As an example, a portion of Team 3 results are shown below. Team 3 was significant because they went from the slowest performance of any team (46.5 minutes; average time for other teams in scenario 1 was 12.5 minutes) to the fastest performance (7 minutes; average time for other teams in scenario 2 was 14.5 minutes). We believe that this team's extreme performance enhancement was due to physiological synchrony of individuals within the team, and with the emergence of a physiological leader (as shown by salivary cytokine concentrations for Team 3 at right) before the second attempt. Note: In post-survey questionnaire, Team 3 did not identify any member as a leader and yet leadership was observed. The concept of salivary cytokine concentrations relating to leadership is supported by additional data from other teams in the second figure below.



Team 3 went from the worst performance to the best performance during a mock hostage rescue scenario based upon time (from 46.5 minutes to 7.5 minutes); Shannon Data Filter (of physiological responses) synchrony increased 3.4x (Δ0.51→ Δ0.15). The non-smoothed Shannon Data Filter responses are shown in the small inset boxes; note: synchrony is achieved by all subjects increasing their response to match Subject 115. Salivary concentrations of cortisol and cytokines (IL-1b, IL-10, IL-8, GM-CSF) are shown at right for each subject; note: prior to Scenario 2, Subject 115 showed ~3X decrease in salivary cytokines when compared to other subjects in his team.



Aggregated salivary cytokine concentrations (summed for all scenarios) for 4 different teams. In post-scenario surveys, subjects labeled with ◆ were identified as primary leaders of the team; team 3 indicated that there was no leader. Lower salivary cytokine responses appear to be related to leadership within a team.

LINKING BIOMARKERS TO MISSION SUCCESS

The mock hostage rescue missions that were performed by each subject as an individual and as part of a four person team at the WVU crime scene complex provided some extremely useful information about subject performance, leadership, and task efficiency. To understand how these metrics correspond to physiologically relevant biomarkers in blood and saliva, correlation analysis was performed in SAS jmp. Statistically significant correlations between three different metrics (performance, leadership, and efficiency) and subject biomarkers are shown in Table 1 below. The pairwise correlation analysis compared each pair of variables across all subjects (N=16). For some variables, N = 15 because one subject did not provide enough saliva sample during the team tasks to perform all assays necessary. Additionally, during the individual scenarios, one subject did not have their body fat % recorded, therefore N=15 for individual correlations involving body fat %. Any correlations with P > .05 were discarded. Due to potential statistical bias (because all individuals on a team finished at the same time), team performance was not calculated for pairwise correlation analysis. In Table 1, individual plasma initial and individual plasma final are abbreviated as ipi and ipf, respectively. Team plasma initial and team plasma final follow the same style, tpi and tpf, respectively. For GSH, abbreviations are "individual initial (ii), individual final (if), team initial (ti), and team final (tf)," because GSH was measured in the erythrocyte lysate (i.e. intracellular components of red blood cells). For salivary samples, the abbreviation style is the same, where individual saliva sample 1 is "is1" and team saliva sample 1 is "ts1," and so forth.

The sampling collection times for individual and team missions follow the scheme below:
Plasma/blood Initial --> Saliva 1 --> CSH1 --> Saliva 2 --> CSH2 --> Saliva 3 --> CSH3 --> Saliva 4--> Plasma/blood Final

The variables highlighted in RED were negatively correlated, while those in GREEN represent positively correlated variables.

Table 1.

PERFORMANCE						
Variable	**by Variable**	**Correlation**	**N**	**Lower 95%**	**Upper 95%**	**P value**
CSH2_time (indiv)	ACTH_ipf	0.5638	16	0.0946	0.8281	0.0229
CSH2_time (indiv)	ACTH_ipi	0.606	16	0.1577	0.8472	0.0128
CSH2_time (indiv)	BMI	-0.5847	16	-0.8376	-0.1253	0.0174
CSH3_time (indiv)	BMI	-0.4978	16	-0.7969	-0.0027	0.0498
CSH2_time (indiv)	Body_fat_%	-0.626	15	-0.8619	-0.1675	0.0125
CSH3_time (indiv)	Body_fat_%	-0.5907	15	-0.8467	-0.1125	0.0204
CSH1_time (indiv)	Chloride_ipi	0.5287	16	0.0448	0.8117	0.0352
Indiv_ total time	Chloride_ipi	0.5321	16	0.0495	0.8133	0.0339
CSH3_time (indiv)	Cortisol_is3	0.5086	16	0.0173	0.8021	0.0442
LEADERSHIP						
Variable	**by Variable**	**Correlation**	**N**	**Lower 95%**	**Upper 95%**	**P value**
Leadership Score_CSH2	ACTH_tpf	-0.5692	16	-0.8305	-0.1023	0.0214
Leadership Score_CSH3	Glucose_tpf	0.5286	16	0.0446	0.8117	0.0353
Leadership Score_CSH1	GM-CSF_ts3	-0.5182	16	-0.8067	-0.0303	0.0398
Leadership Score_overall	GM-CSF_ts3	-0.5572	16	-0.825	-0.0849	0.025
Leadership Score_CSH1	GSH_ti	-0.504	16	-0.7999	-0.0111	0.0465
Leadership Score_overall	GSH_ti	-0.4992	16	-0.7976	-0.0047	0.049
Leadership Score_CSH1	IFNg_ts3	-0.5314	16	-0.813	-0.0485	0.0341
Leadership Score_overall	IFNg_ts3	-0.5838	16	-0.8372	-0.124	0.0176
Leadership Score_CSH1	IL1b_ts1	-0.6571	16	-0.8696	-0.2394	0.0057
Leadership Score_CSH1	IL1b_ts2	-0.5685	16	-0.8302	-0.1013	0.0216
Leadership Score_overall	IL1b_ts2	-0.5283	16	-0.8115	-0.0442	0.0354
Leadership Score_CSH1	IL1b_ts3	-0.6217	16	-0.8542	-0.1821	0.0101
Leadership Score_CSH2	IL1b_ts3	-0.5119	16	-0.8037	-0.0218	0.0426
Leadership Score_overall	IL1b_ts3	-0.6565	16	-0.8693	-0.2384	0.0057
Leadership Score_CSH1	IL6_ts1	-0.6142	16	-0.8509	-0.1704	0.0114
Leadership Score_CSH1	IL6_ts2	-0.5728	16	-0.8322	-0.1077	0.0204
Leadership Score_overall	IL6_ts2	-0.4994	16	-0.7976	-0.0049	0.0489
Leadership Score_CSH1	IL6_ts3	-0.5206	16	-0.8078	-0.0335	0.0387
Leadership Score_overall	IL6_ts3	-0.567	16	-0.8295	-0.0992	0.022
Leadership Score_CSH1	IL8_ts3	-0.5629	16	-0.8277	-0.0932	0.0232
Leadership Score_CSH1	IL8_ts4	-0.53	16	-0.8123	-0.0466	0.0347
Leadership Score_CSH2	Testosterone_tpi	-0.5187	16	-0.8069	-0.0309	0.0395
Efficiency (individual)						
Variable	**by Variable**	**Correlation**	**N**	**Lower 95%**	**Upper 95%**	**P value**
Activity/time(s)_CSH1_indiv	ACTH_ipf	-0.5083	16	-0.802	-0.0169	0.0444
Activity/time(s)_CSH1_indiv	ACTH_ipi	-0.5576	16	-0.8252	-0.0856	0.0248
Activity/time(s)_CSH2_indiv	ACTH_ipi	-0.5838	16	-0.8372	-0.124	0.0176
Activity/time(s)_CSH1_indiv	Cl_ipi	-0.7502	16	-0.9082	-0.4052	0.0008
Activity/time(s)_CSH2_indiv	Cl_ipi	-0.6728	16	-0.8763	-0.2657	0.0043
Activity/time(s)_SumCSH123_indiv	Cl_ipi	-0.7573	16	-0.911	-0.4188	0.0007
Activity/time(s)_CSH1_indiv	Cortisol_is3	-0.5126	16	-0.804	-0.0226	0.0423
Efficiency (team)						
Variable	**by Variable**	**Correlation**	**N**	**Lower 95%**	**Upper 95%**	**P value**
Activity/time(s)_CSH1_team	Cortisol_tpf	-0.5012	16	-0.7985	-0.0073	0.048
Activity/time(s)_SumCSH123_team	Cortisol_tpf	-0.6473	16	-0.8654	-0.2233	0.0067
Activity/time(s)_SumCSH123_team	Cortisol_tpi	-0.5507	16	-0.822	-0.0756	0.0271
Activity/time(s)_CSH1_team	GM-CSF_ts1	-0.6387	16	-0.8616	-0.2092	0.0077
Activity/time(s)_CSH2_team	GM-CSF_ts2	0.5265	16	0.0416	0.8106	0.0362
Activity/time(s)_CSH3_team	GM-CSF_ts2	0.5241	16	0.0383	0.8095	0.0372
Activity/time(s)_CSH1_team	IFNg_ts1	-0.5972	16	-0.8433	-0.1441	0.0146
Activity/time(s)_CSH2_team	IFNg_ts2	0.5567	16	0.0842	0.8248	0.0251
Activity/time(s)_CSH1_team	IL1b_ts1	-0.7183	16	-0.8953	-0.3458	0.0017
Activity/time(s)_CSH1_team	IL1b_ts2	-0.5418	16	-0.8179	-0.0631	0.0302
Activity/time(s)_CSH1_team	IL4_ts1	-0.5401	16	-0.8171	-0.0606	0.0308
Activity/time(s)_CSH2_team	IL4_ts2	0.5347	16	0.053	0.8145	0.0328
Activity/time(s)_CSH1_team	IL6_ts1	-0.7248	16	-0.8979	-0.3575	0.0015
Activity/time(s)_CSH1_team	IL8_ts2	-0.5582	16	-0.8255	-0.0865	0.0246
Activity/time(s)_SumCSH123_team	Testosterone_ts1	-0.613	15	-0.8563	-0.1468	0.0151
Activity/time(s)_CSH1_team	TNFa_ts1	-0.547	16	-0.8203	-0.0703	0.0283
Activity/time(s)_CSH2_team	TNFa_ts2	0.5553	16	0.0823	0.8242	0.0255

PERFORMANCE: For the mock hostage rescue missions, the length of time to complete each mission (CSH1, CSH2, or CSH3) was used to describe subject performance (i.e. advanced performance would be the shortest amount of time to complete the mission and poor performance would be the longest amount of time to complete the mission). In CSH1, the subjects are familiarizing themselves with their surroundings in the context of the tasks. Initial chloride concentrations were positively correlated with CSH1 time (i.e. low concentrations of chloride were correlated with shorter amount of time to complete CSH1), showing that initial chloride levels may be predictive of CSH1 performance. The best mission/scenario to determine subject performance would be CSH2, where the subjects are informed to go as fast as possible. For this mission/scenario, ACTH was positively correlated with CSH2 performance, whereas BMI and body fat % were negatively correlated to mission performance . BMI and body fat % negatively correlated to CSH2 performance is a surprising finding- the higher your BMI or body fat %, the faster you went (took less time to complete CSH2). Performance during the failure task (CSH3) is positively correlated to salivary cortisol concentrations, whereas BMI and body fat % were negatively correlated to CSH3 performance (similar to CSH2).

LEADERSHIP: While completing the mock hostage rescue scenarios/missions as part of a four person team, subjects were given a simple post-mission survey to be completed after each mission (CSH1, 2, and 3) and an "overall" survey to describe their own assessment of performance, communication, leadership, etc. In this survey, subjects were asked to state who on their team was the leader(s) for each mission, and who was the overall leader (consistent leader for all missions). To score these responses, the subject that was indicated as the leader received a score of 1, totaling 4 if all subjects selected the same individual as their leader. Some subjects indicated 2 people as the leader for a particular mission, therefore their score was recorded as 0.5 (i.e. 0.5 for subject X and 0.5 for subject Y if a team member said "subjects X and Y were leaders for this mission"). The "Overall leader" leadership score is not a

Leadership Scores

Team & Subject	CSH1	CSH2	CSH3	Overall Leadership
Team 1				
102	1.5	0.5	0.5	0.5
103	2.5	0.5	0.5	1.5
104	0	0	0	0
110	0	0	0	0
Team 2				
105	0	0	0	0
108	3	3	4	4
112	0	0	0	0
113	0	0	0	0
*Team 3**				
106	0	0	0	0
111	0	0	0	0
115	0	0	1	0
116	1	1	0	1
Team 4				
107	0	0	0	0
109	0	0.5	0.5	0
114	1.5	2	0.5	3
117	0.5	0.5	0	0

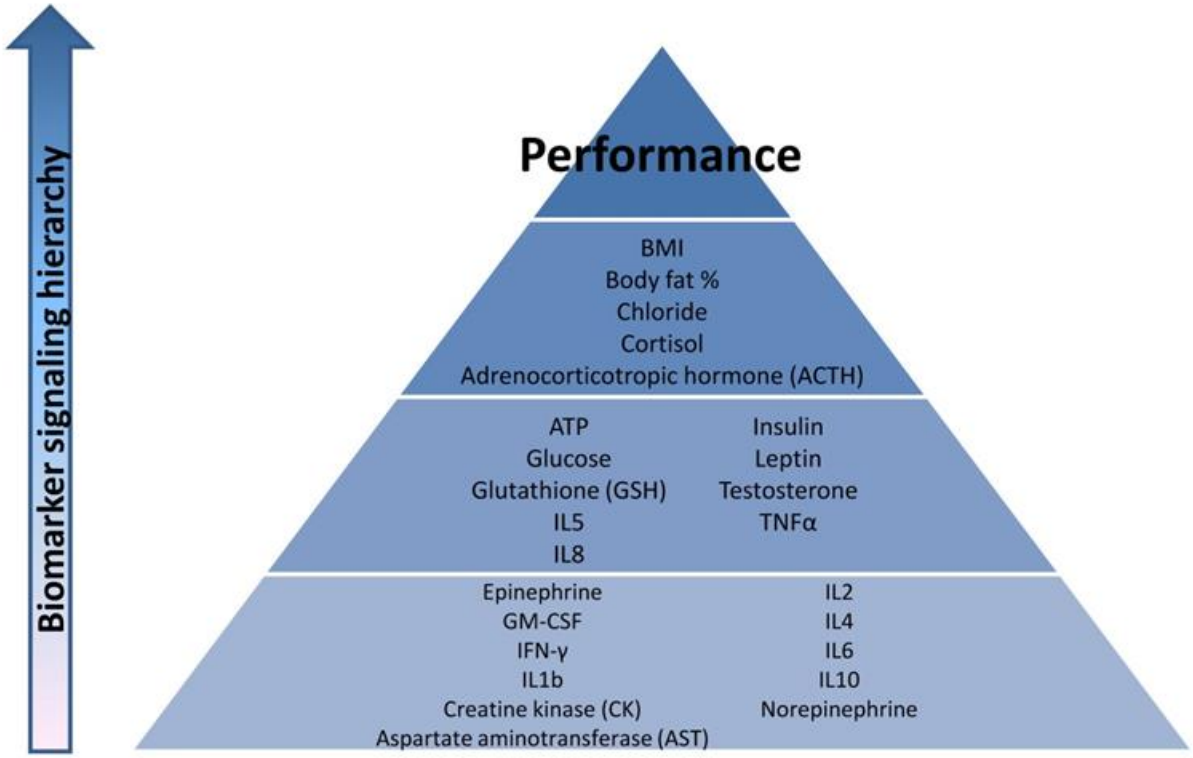
sum of the three missions; rather it is an independent score from the overall mission success survey where subjects answered the question, "Was there an apparent leader of the group overall [encompassing all 3 missions]?" The asterisk on Team 3 corresponds to their leadership scores indicating no real leader; however from post-video analysis, we can see that subject 111 was more of a social leader and subject 115 appeared to be a physiological leader. From these leadership scores (shown above), we performed correlation analysis on the leadership scores with blood/plasma and salivary biomarkers. In Table 1, initial GSH blood concentrations are inversely proportional to CSH1 and overall leadership scores (lower blood GSH concentrations are related to higher leadership scores), implicating GSH as a predictive biomarker of demonstrated leadership. Also, final ACTH plasma concentrations are inversely proportional to CSH2 leadership scores (the task where the teams are told to go as fast as they can). Finally, various salivary markers, such as GM-CSF, IFN-γ, IL1b, IL6, IL8 as well as plasma testosterone are all inversely proportional to CSH1, CSH2, and/or overall leadership scores; thus subjects with a high leadership score have lower salivary or plasma concentrations of these biomarkers. However, for the "failed" mission (CSH3), leadership scores were proportional to final plasma glucose concentrations (taken immediately following completion of CSH3).

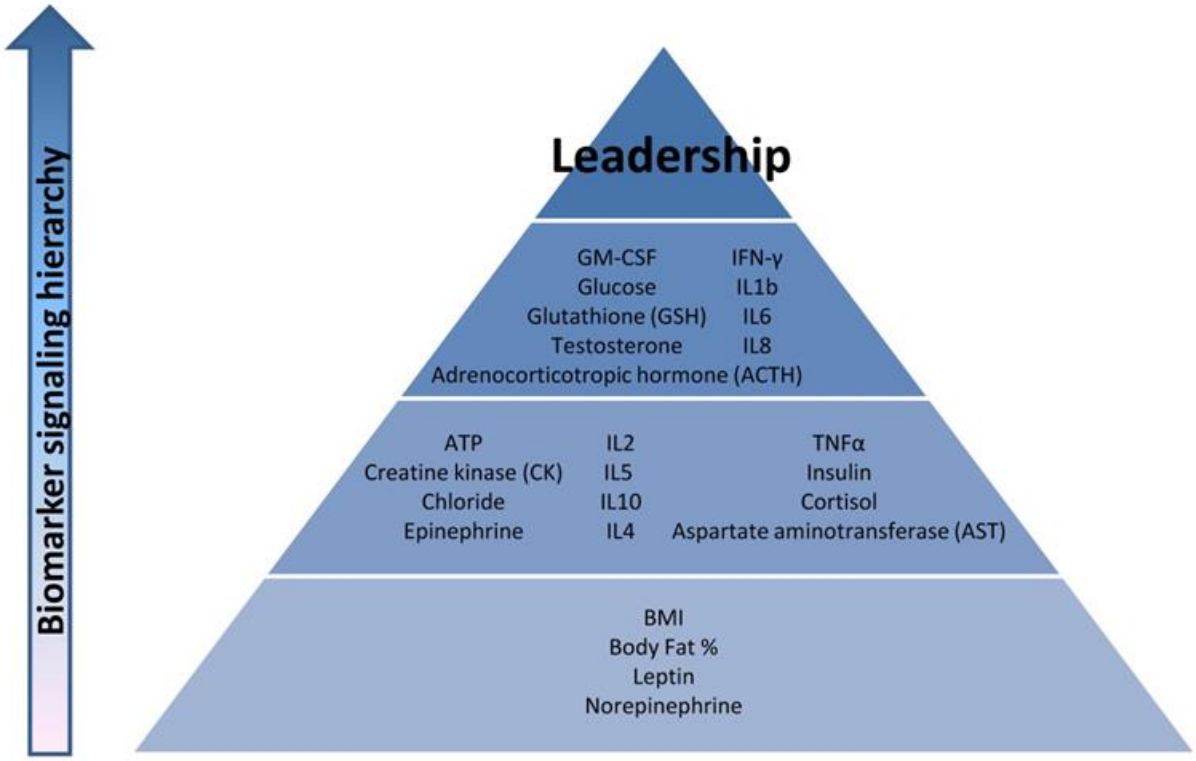
EFFICIENCY: The zephyr external monitor measures several metrics, one of which is activity. To determine subject efficiency during a given mission, we summed an individual's activity during that scenario and divided by the time it took to complete that scenario/mission (i.e. total activity for CSH1 divided by total time to complete CSH1). Since we described activity/time in this manner, efficiency can also be called average activity per second. A high activity/time value could represent low efficiency (inefficiency), where many movements were needed to complete the mission. These calculations were performed for missions where subjects completed the scenarios/missions as an individual (Efficiency individual) and team efficiency was calculated by summing the individual's activity for each scenario and dividing by their respective team's time to complete a given task (i.e. subject 102's summed activity for CSH1(team) was divided by the time it took for team 1 to complete CSH1, since 102 is on team 1). As an individual, efficiency was correlated with subject initial and final ACTH plasma concentrations, initial chloride plasma concentrations and cortisol 3 (collected after CSH2) salivary concentrations. However, these biomarkers were not significantly correlated to efficiency when the subjects were part of a four person team; this may be due to the distribution of work when part of a team and varied leadership roles. As a team, efficiency was correlated with subject initial and final plasma cortisol concentrations and several salivary cytokines (GM-CSF, IFN-γ, IL1b, IL4, IL6, IL8, TNFα) as well as initial saliva testosterone concentrations.

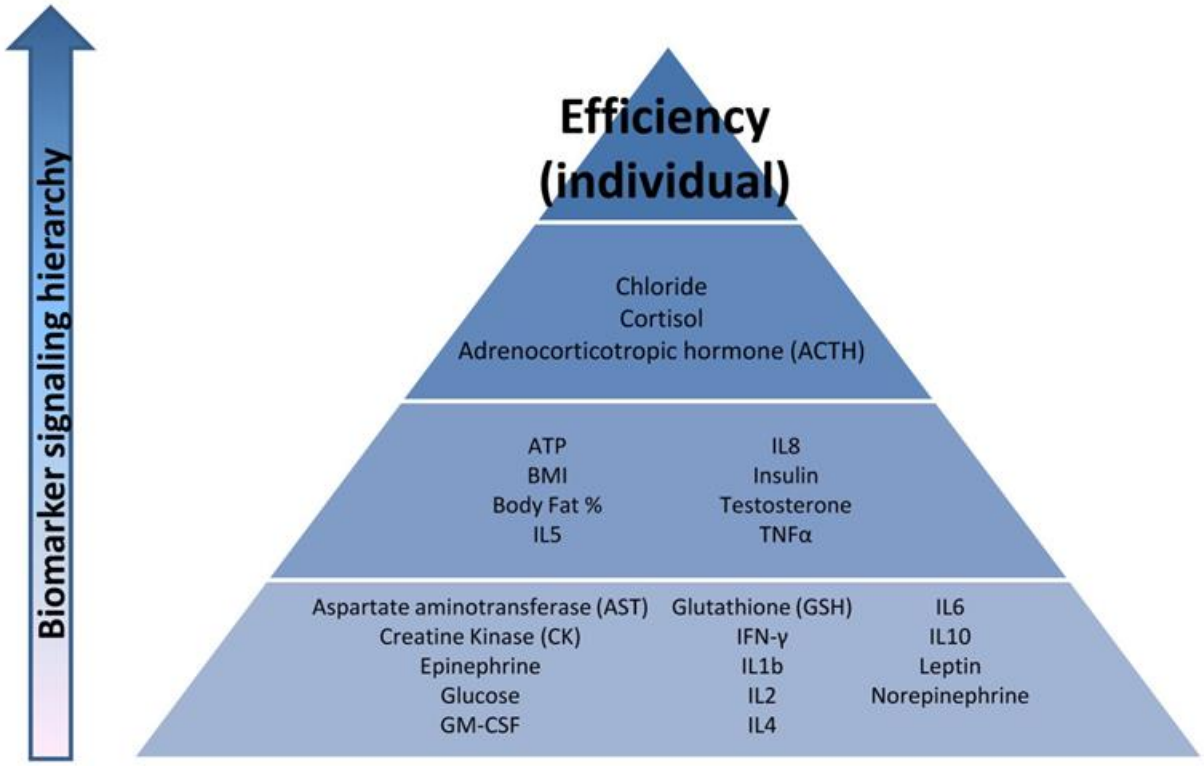
Determining biomarker signaling hierarchy via pairwise correlation analysis

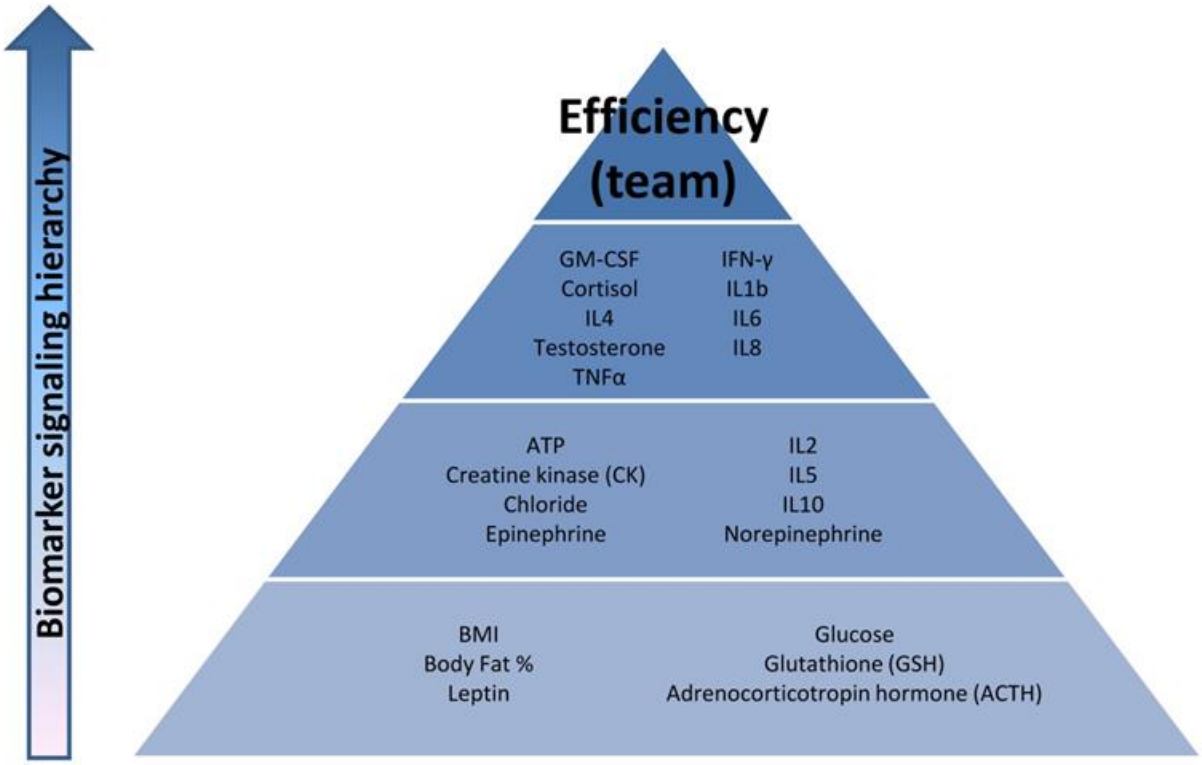
In order to determine the biological significance and a hierarchy of biological importance to mission-success parameters, such as performance, leadership, and efficiency, we performed pairwise correlation analysis across all biomarkers measured, and structured them as they are related to the mission-success parameters of interest. Below, we have described the biomarker signaling hierarchy in relation to mission performance, leadership, and mission efficiency. The biomarker signaling hierarchy can be visualized with a pyramid, where the first tier is correlated to the second tier, the second tier is correlated to the third tier, and the third tier is correlated to

the fourth tier. Specific correlation connections can be found in the attached excel file "correlation indiv_performance".



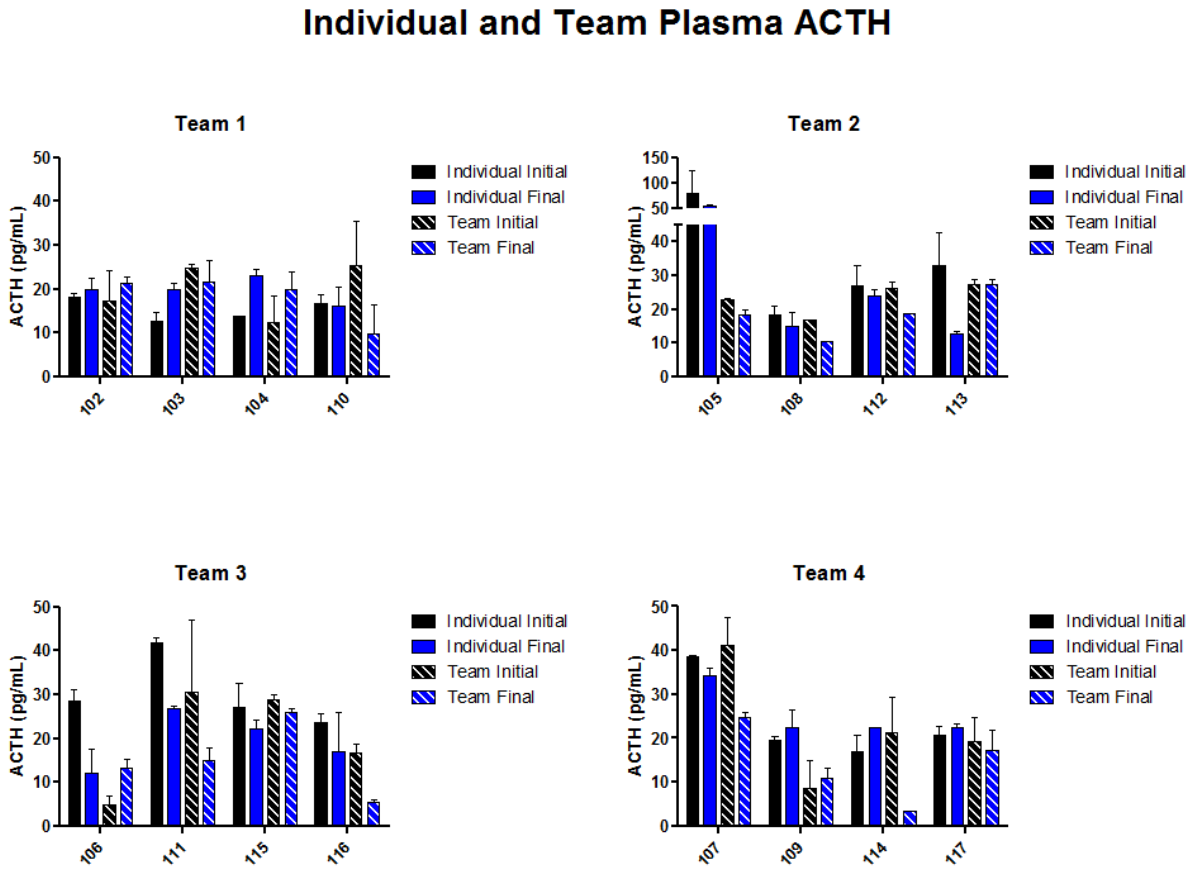



Biomarker signaling hierarchy
Efficiency (individual)
Chloride
Cortisol
Adrenocorticotropic hormone (ACTH)
ATP
BMI
Body Fat %
IL5
IL8
Insulin
Testosterone
TNFα
Aspartate aminotransferase (AST)
Creatine Kinase (CK)
Epinephrine
Glucose
GM-CSF
Glutathione (GSH)
IFN-γ
IL1b
IL2
IL4
IL6
IL10
Leptin
Norepinephrine

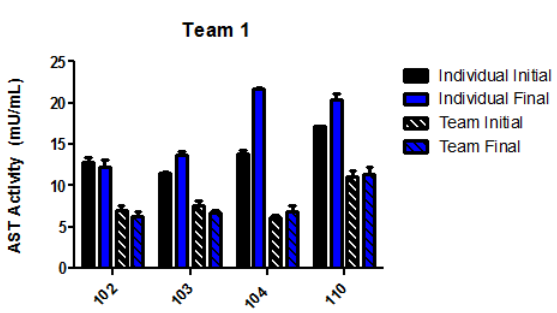

Biomarker signaling hierarchy
Efficiency (team)
GM-CSF
Cortisol
IL4
Testosterone
TNFα
IFN-γ
IL1b
IL6
IL8
ATP
Creatine kinase (CK)
Chloride
Epinephrine
IL2
IL5
IL10
Norepinephrine
BMI
Body Fat %
Leptin
Glucose
Glutathione (GSH)
Adrenocorticotropin hormone (ACTH)

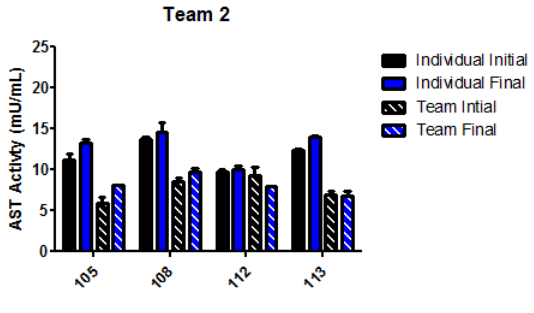
As you can see from efficiency (team) and leadership hierarchy pyramids, the biometrics contributing to these desired endpoints are very similar. This means that some of these biomarkers are driving both leadership and individual efficiency while on a four person team. However, it is important to note that leadership scores and team efficiency is not correlated to each other. Again, this shows that while characteristics/biomarkers indicative of leadership are also related to efficiency, leadership itself (as tabulated from post-scenarios surveys) is not related to efficiency. Could some combination of leadership biomarkers and efficiency biomarkers be indicative of superior mission performance? Further experimentation and model development are necessary to combine these metrics into overall advanced mission success.

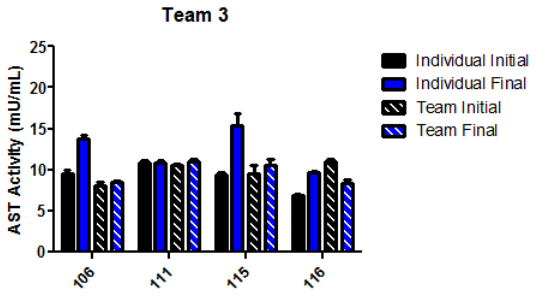
APPENDIX I:
ENDOGENOUS BIOMARKER DATA

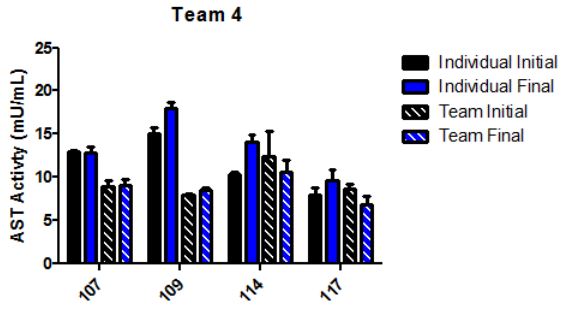


Individual and Team Plasma AST

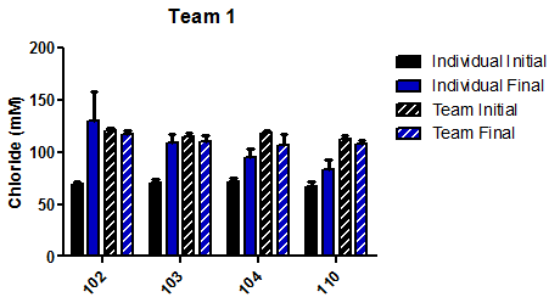


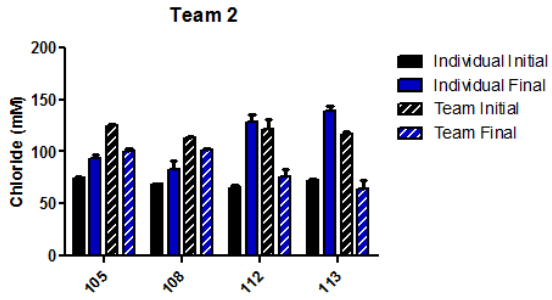


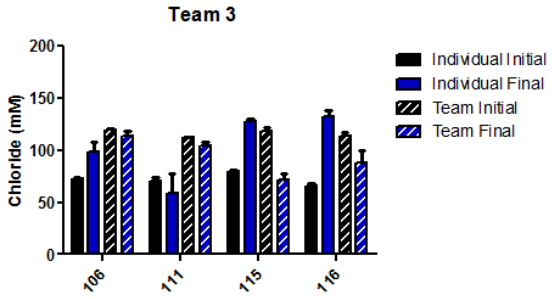


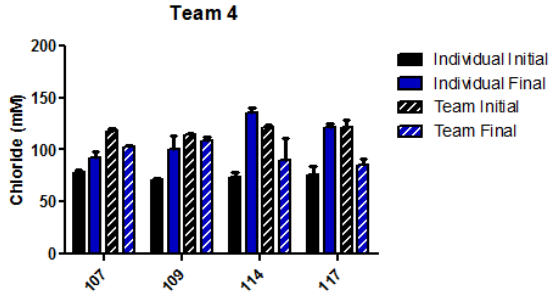


Individual and Team Plasma Chloride

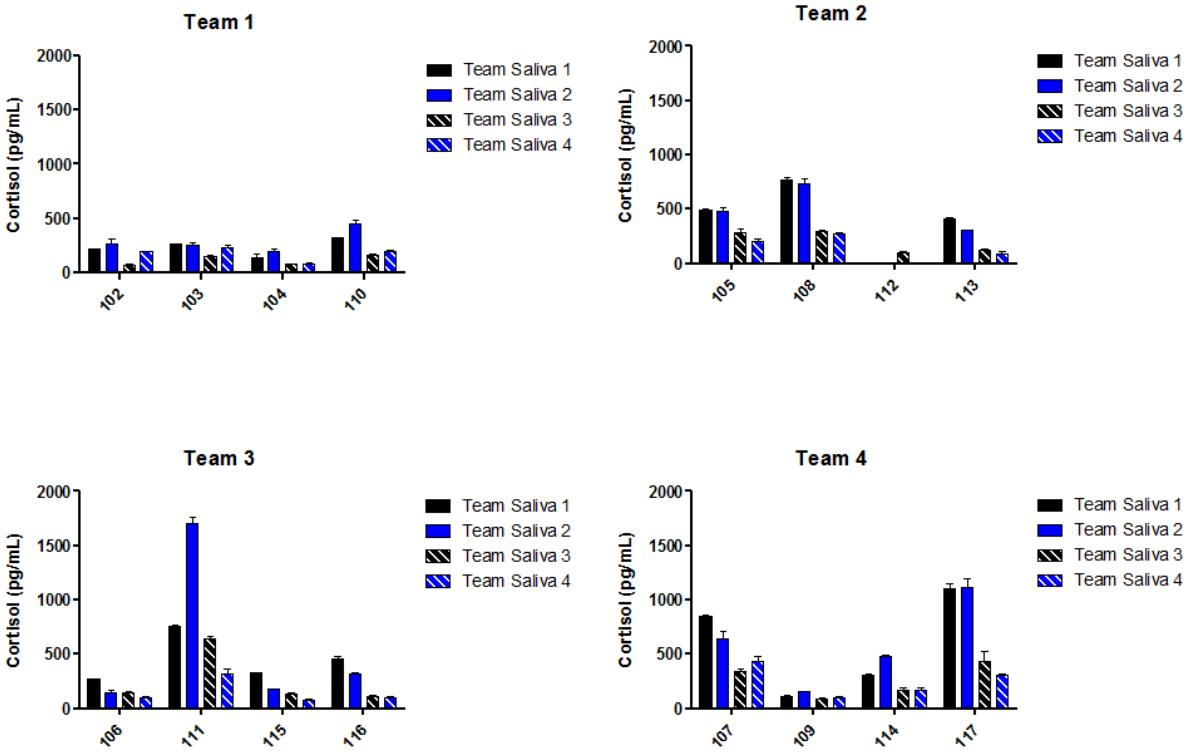




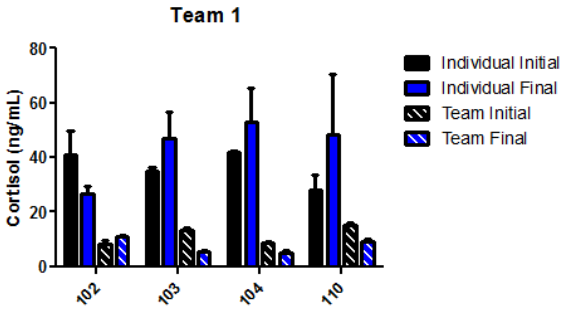


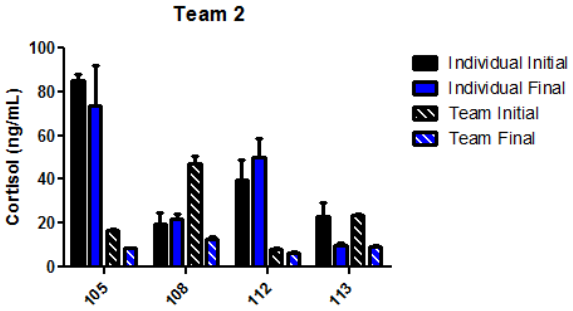


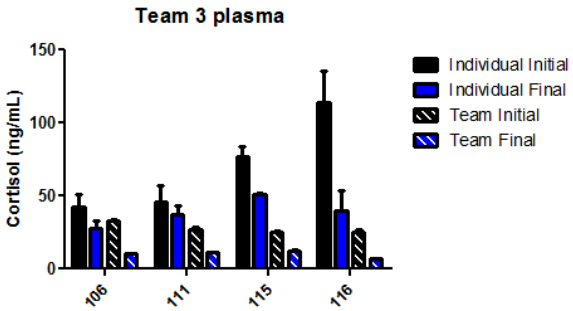
Team Saliva Cortisol

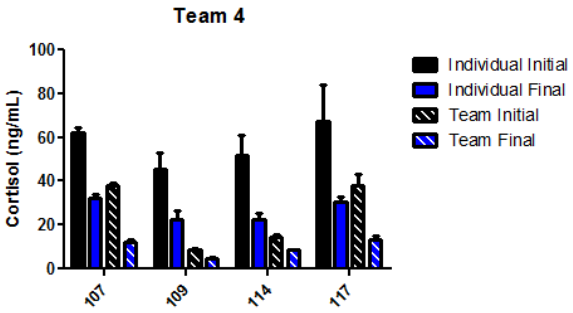


Individual and Team Plasma Cortisol

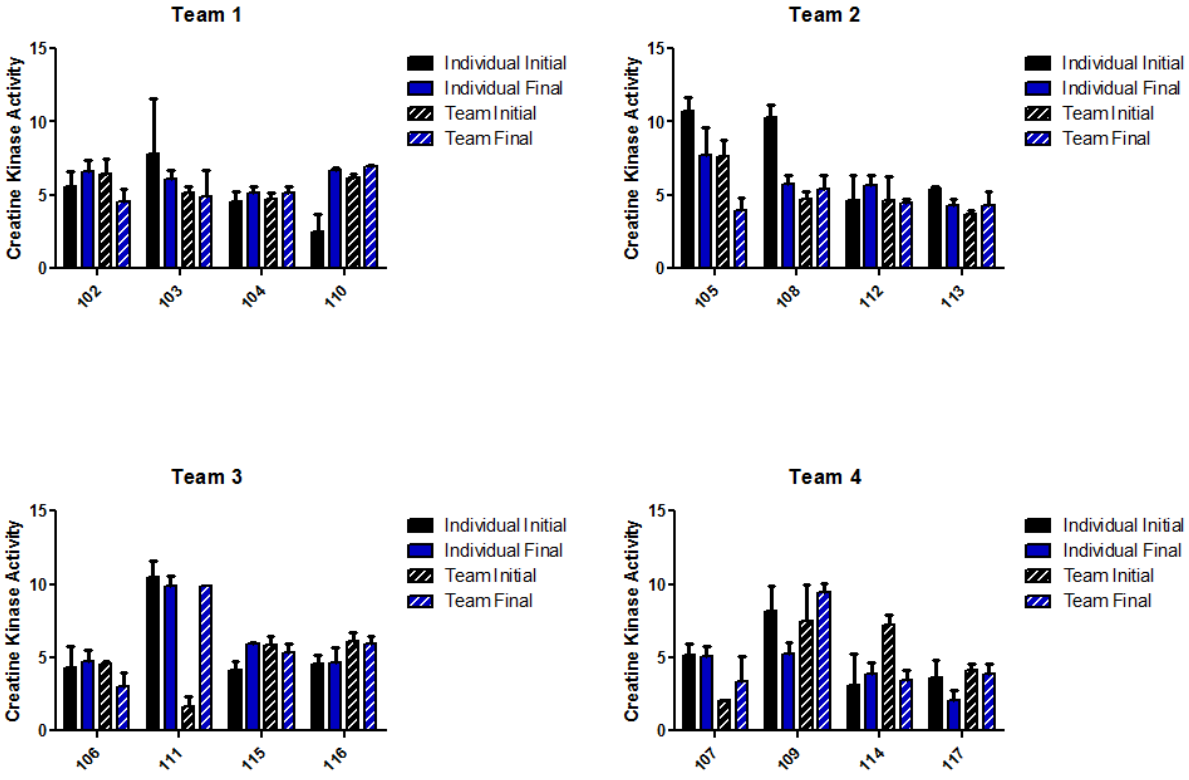




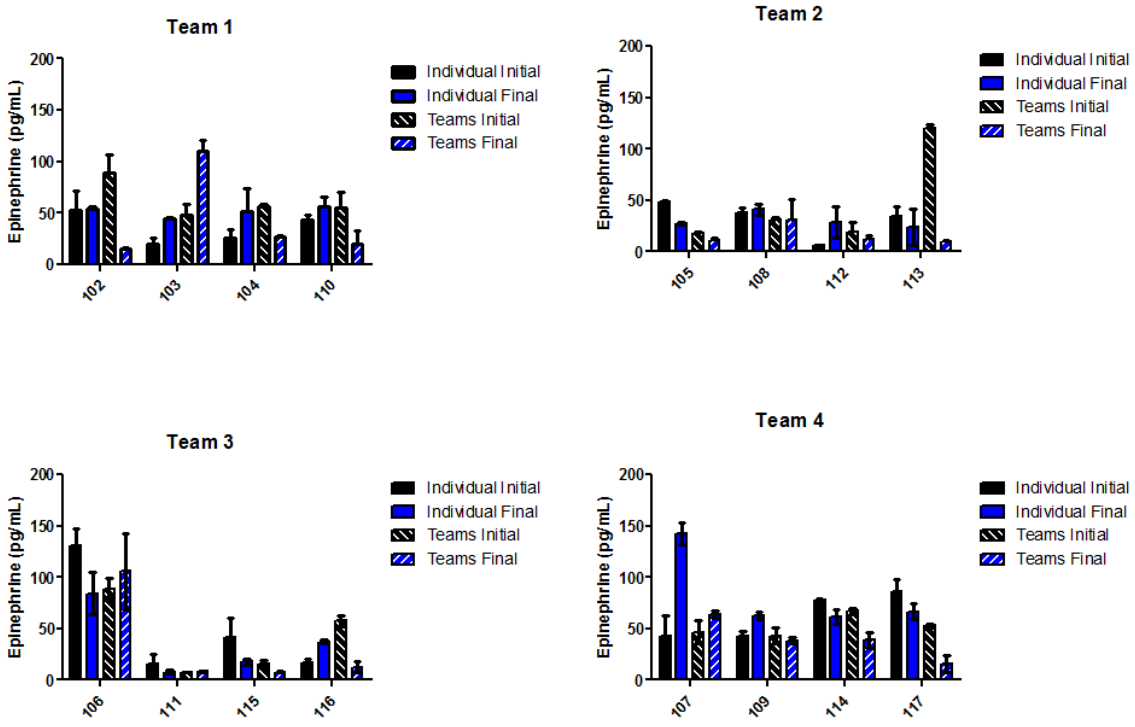




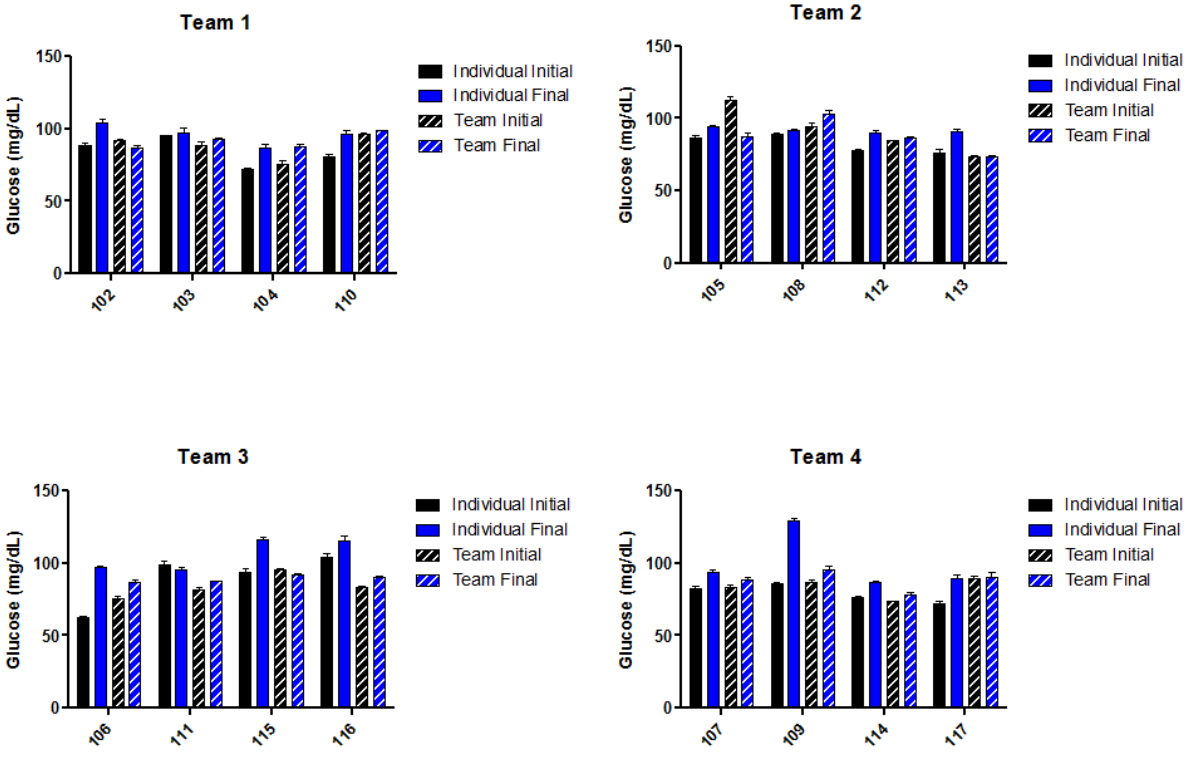
Individual and Team Plasma Creatine Kinase



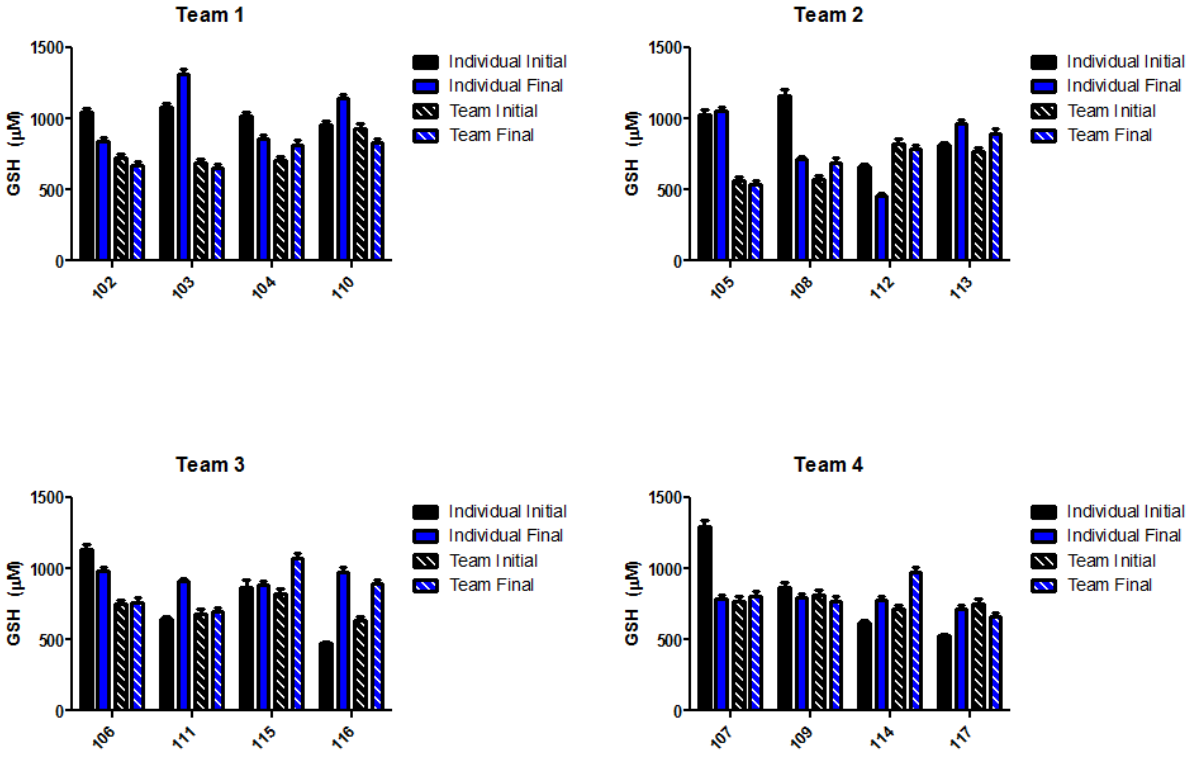
Individual and Team Plasma Epinephrine



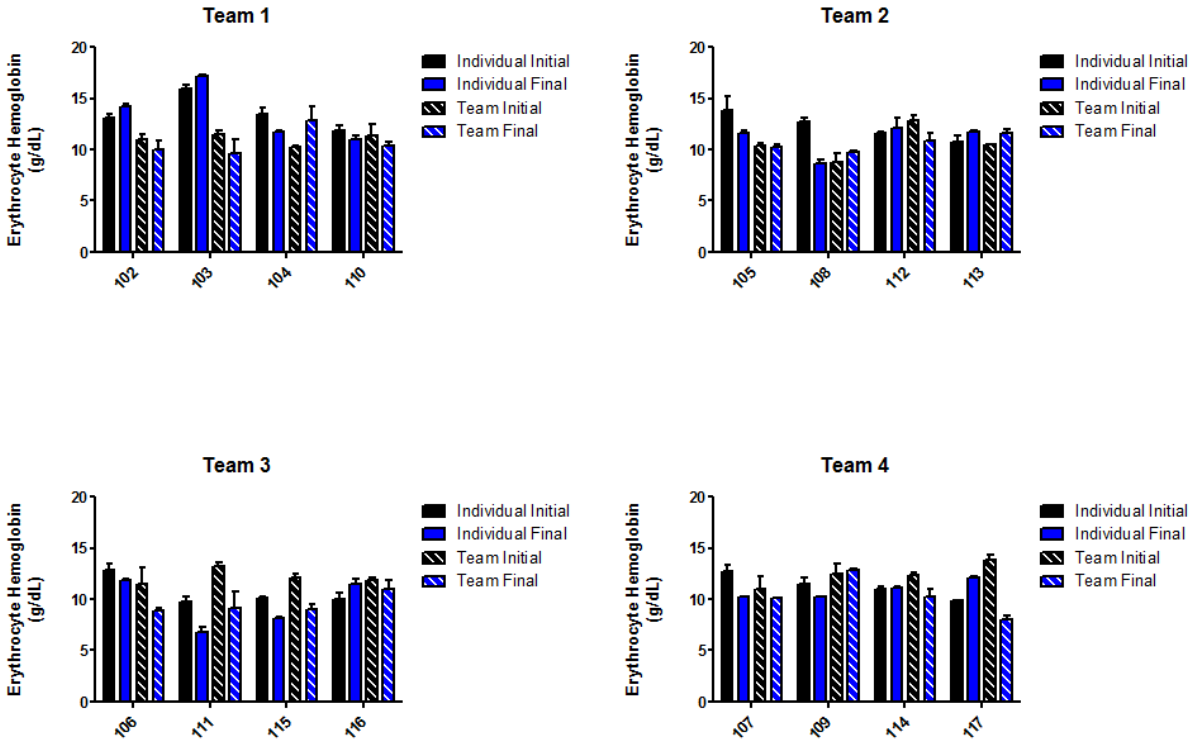
Individual and Team Plasma Glucose



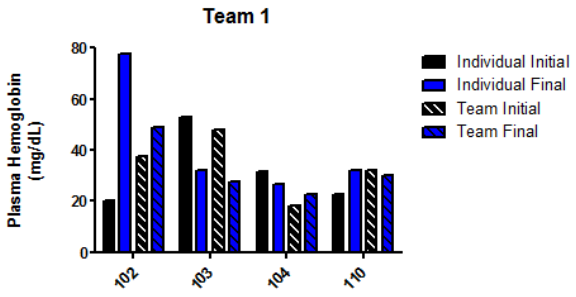
Individual and Team Plasma GSH

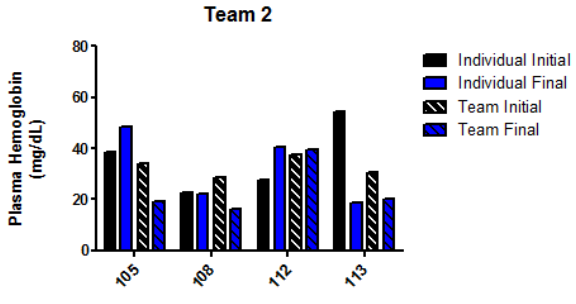


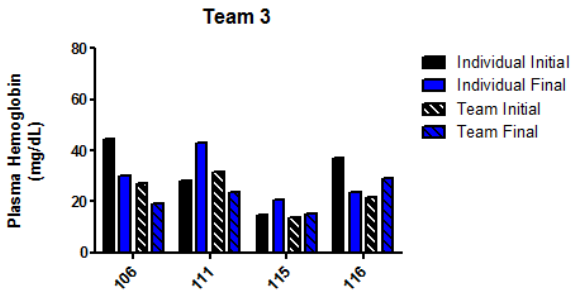
Individual and Team Erythrocyte Hemoglobin

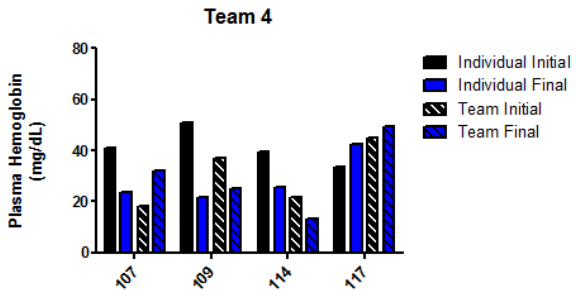


Individual and Team Plasma Hemoglobin

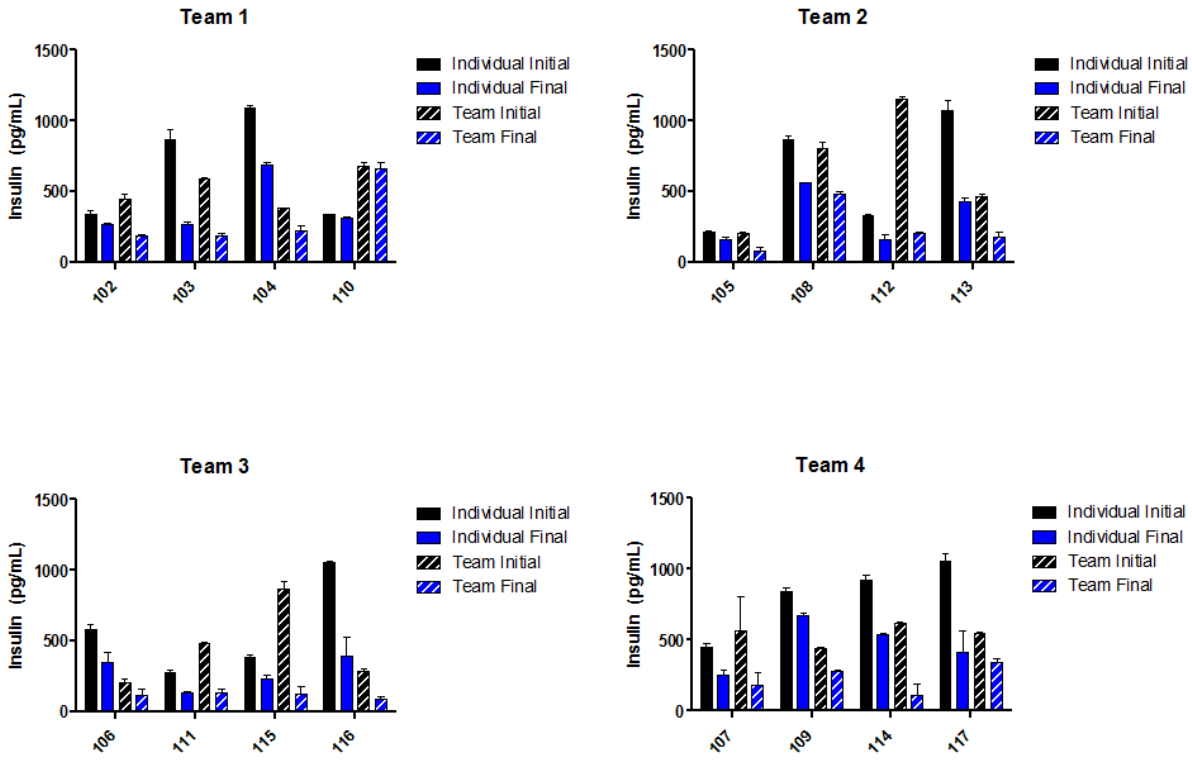




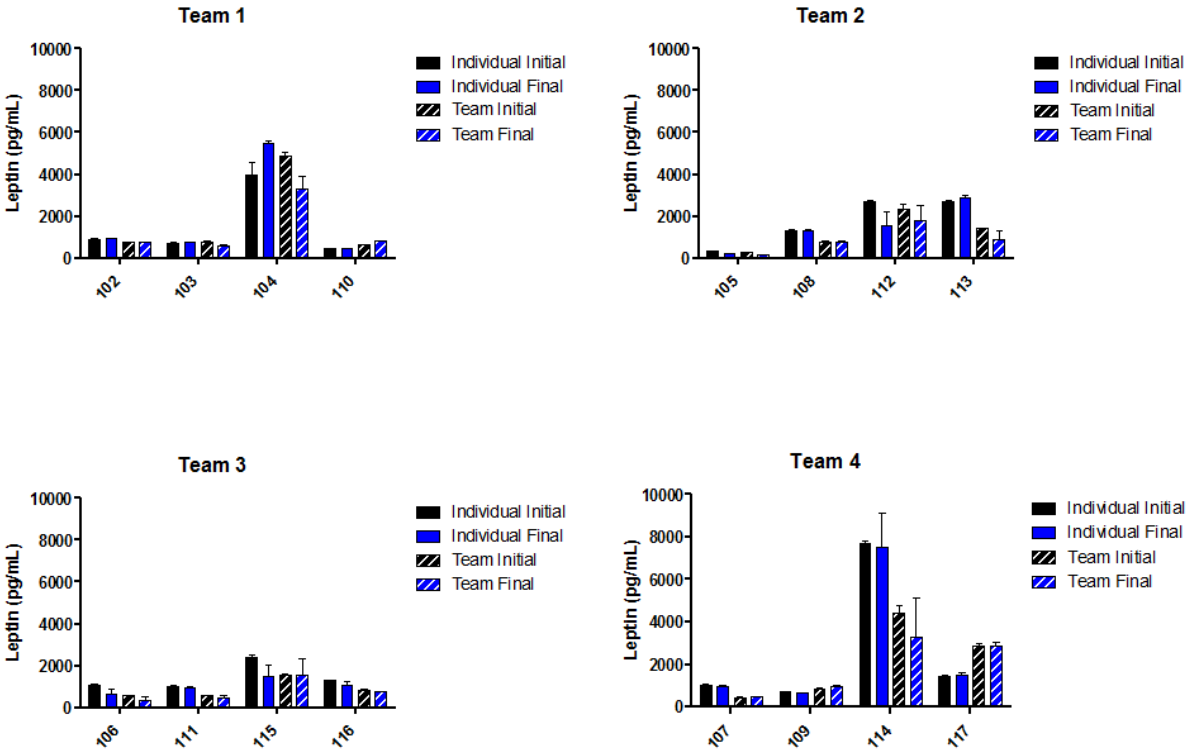




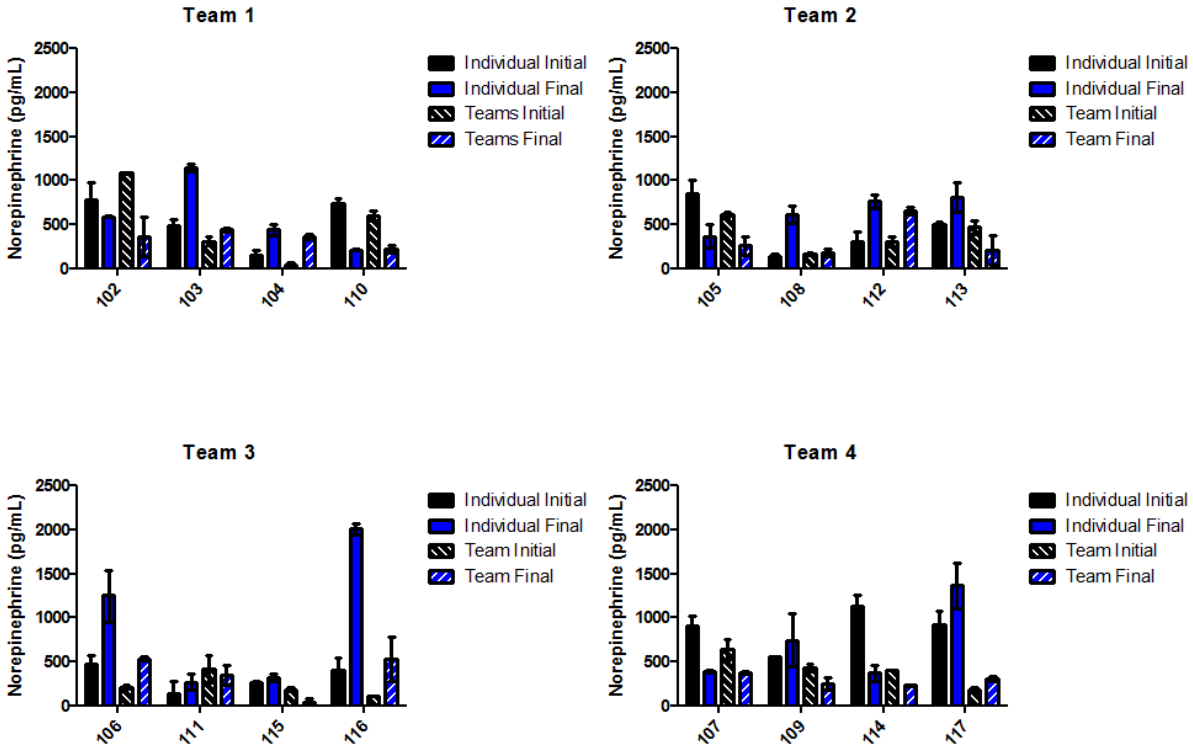
Individual and Team Plasma Insulin



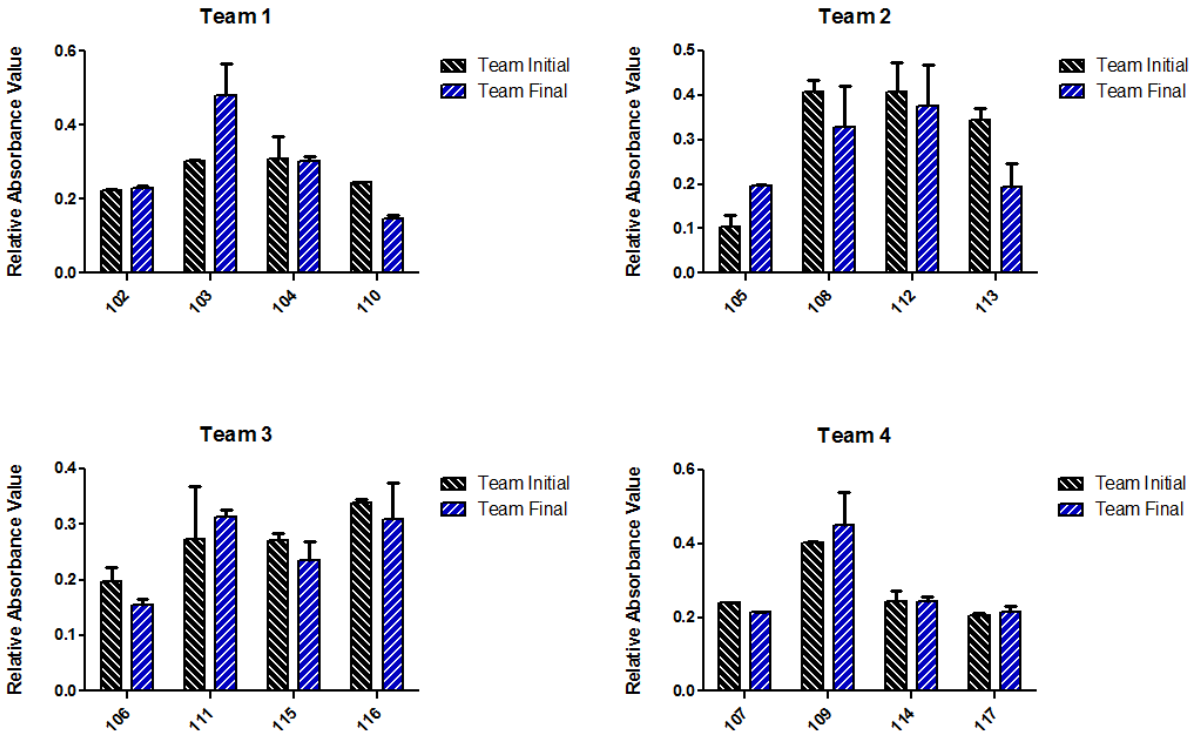
Individual and Team Plasma Leptin



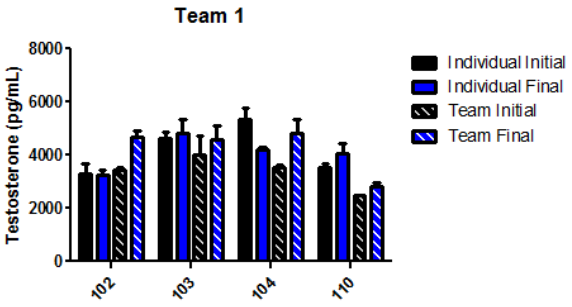
Individual and Team Plasma Norepinephrine

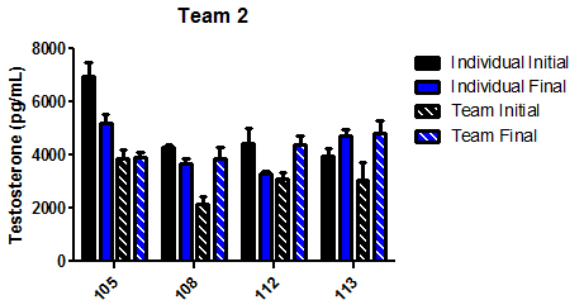


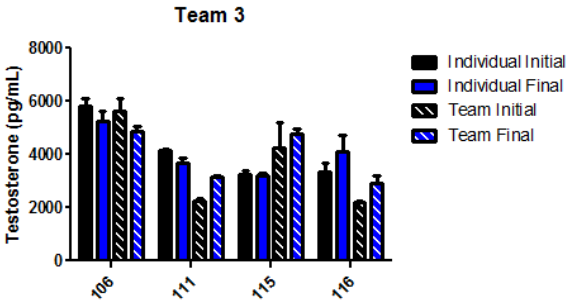
Team Plasma Prolactin

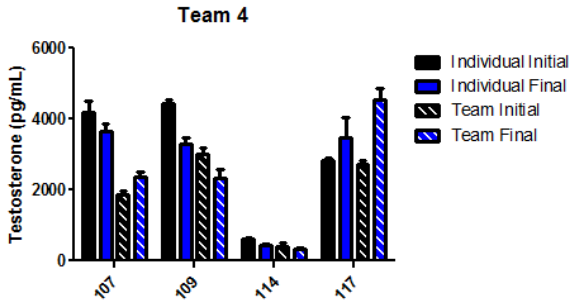


Individual and Team Plasma Testosterone

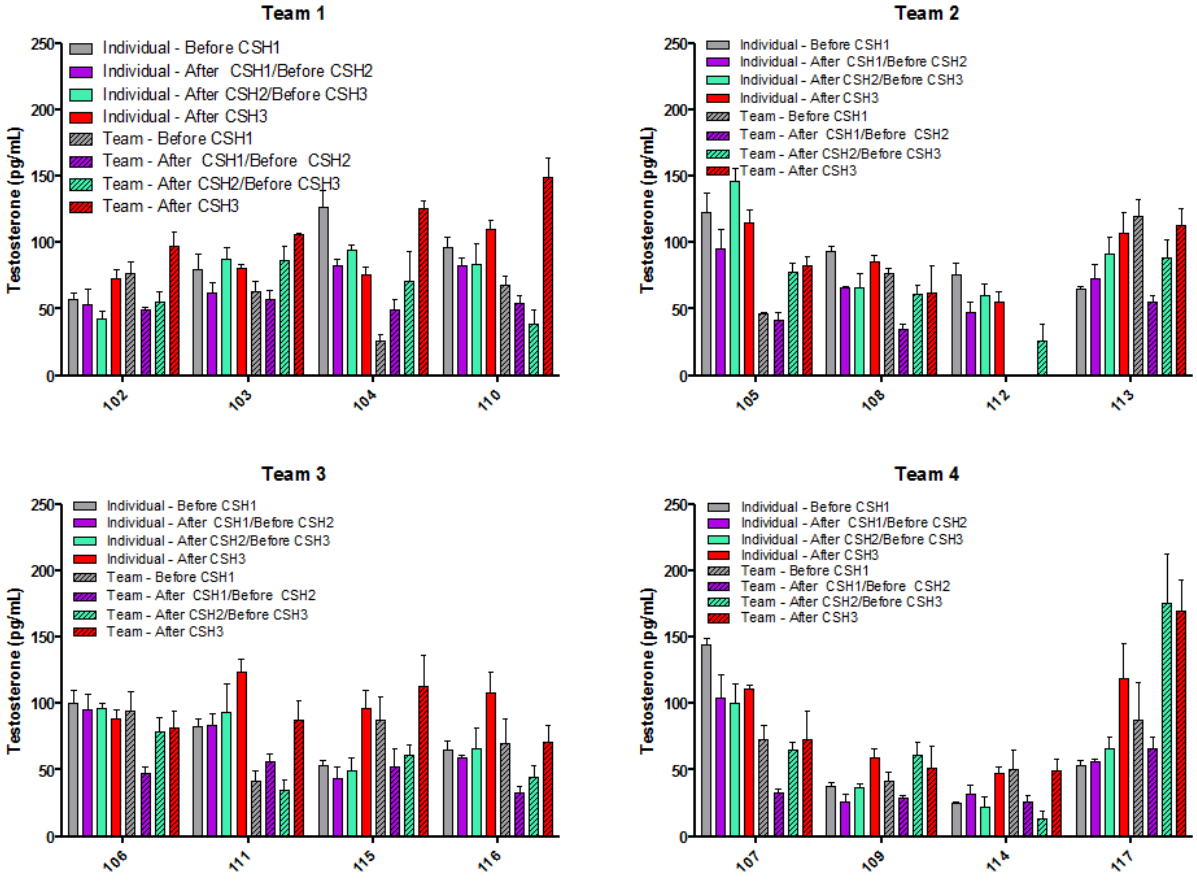




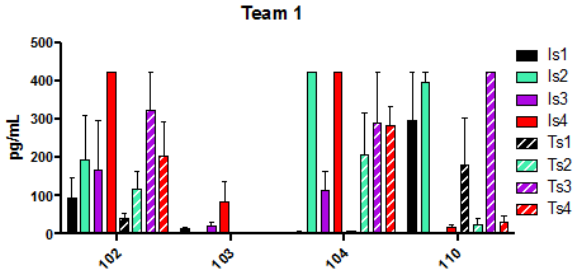


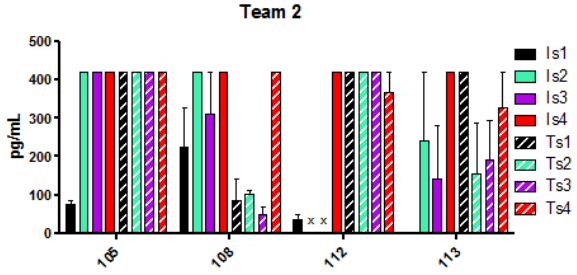


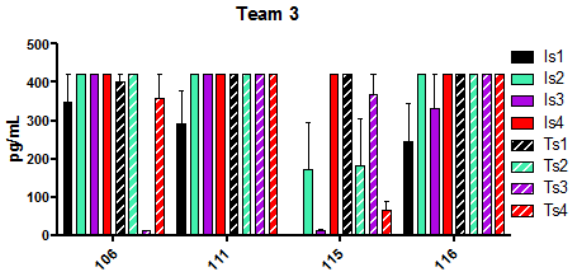
Individual and Team Saliva Testosterone

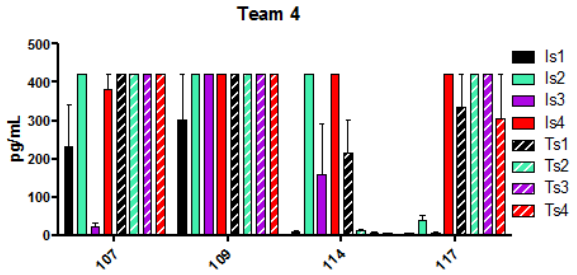


Individual and Teams Saliva IL-1b

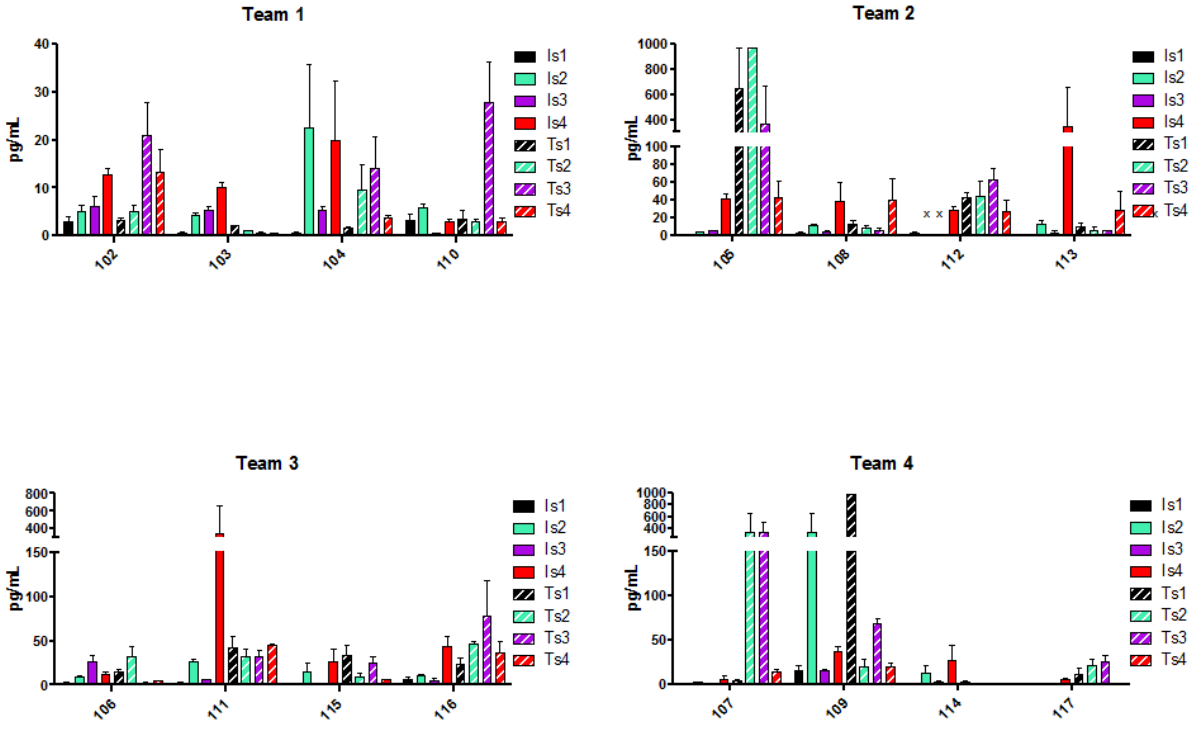




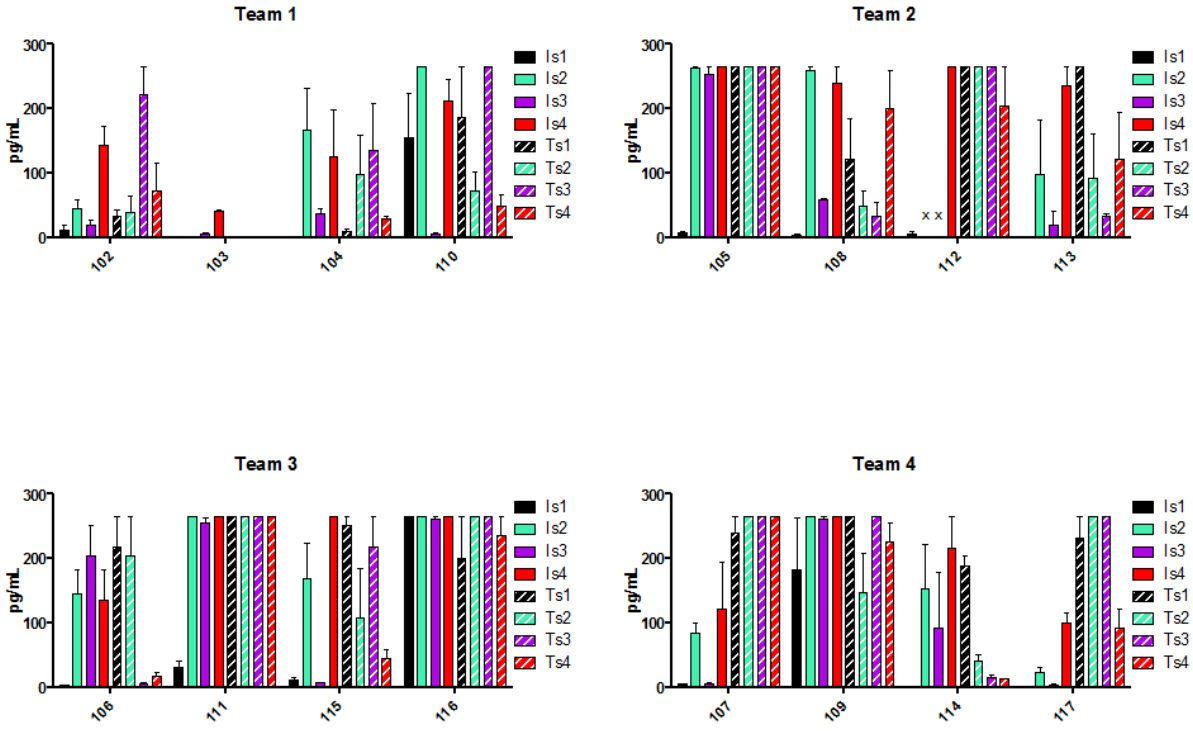




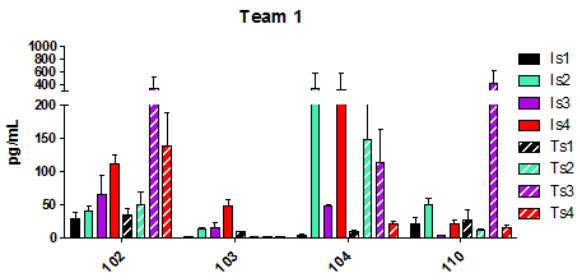
Individual and Team Saliva IL-10

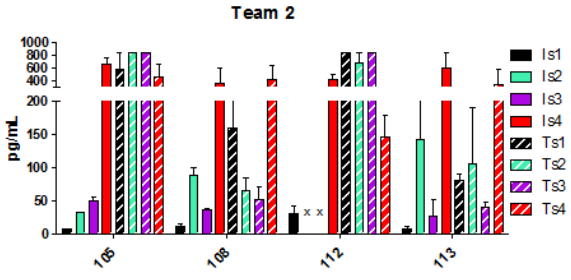


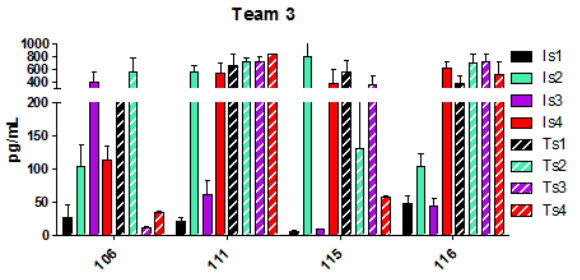
Individual and Team Saliva IL-6

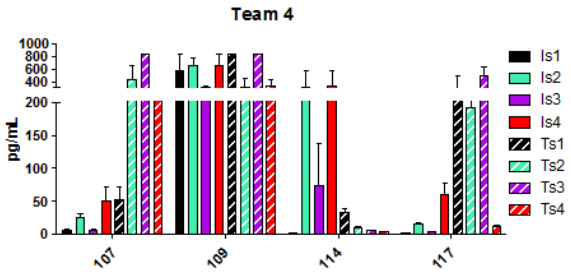


Individual and Team Saliva IL-4

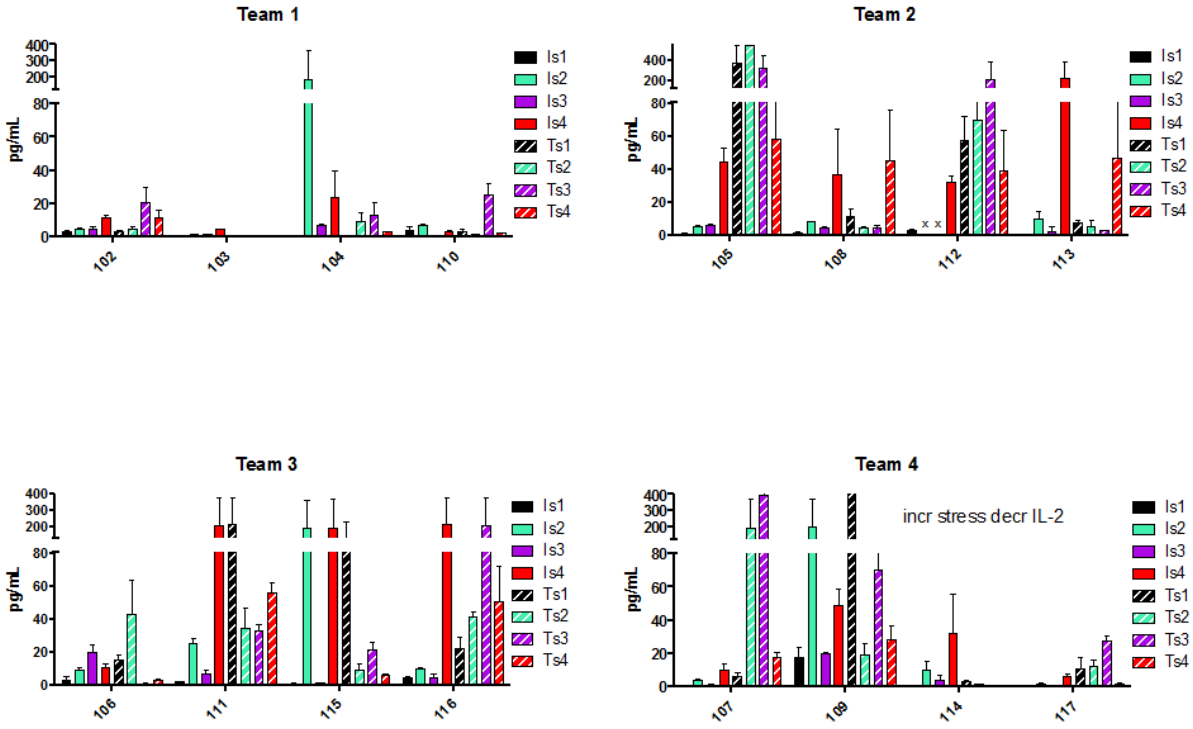




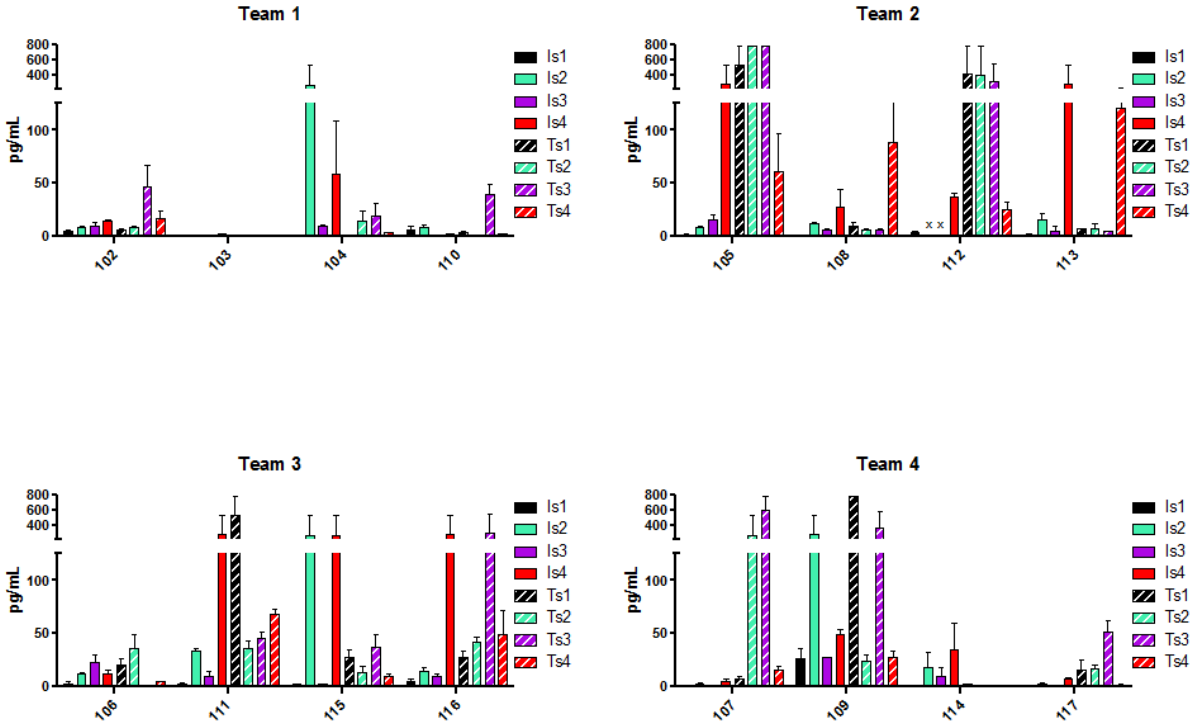




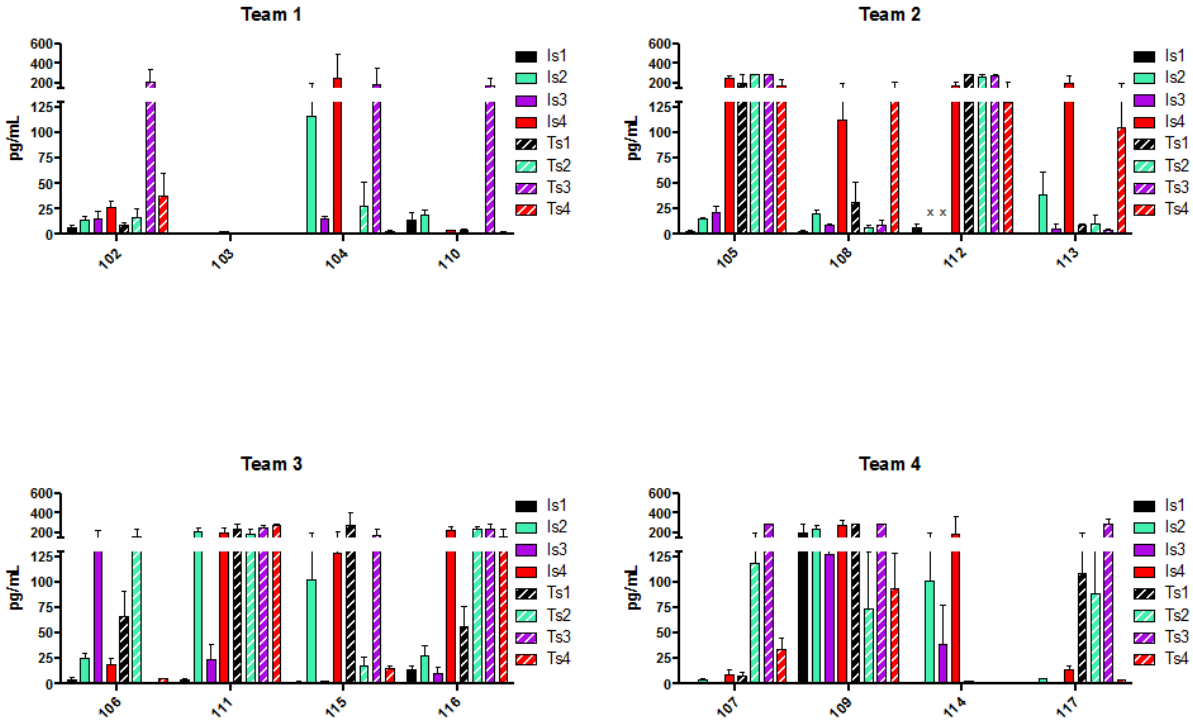
Individual and Team Saliva IL-2



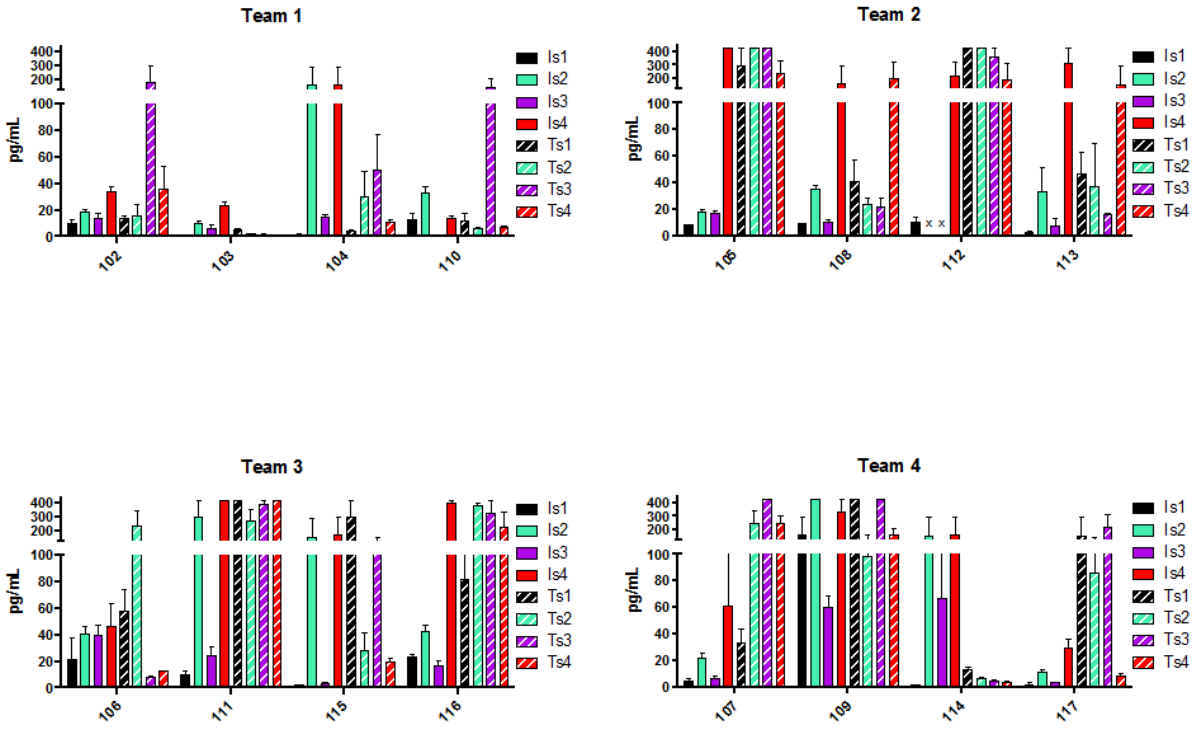
Individual and Team Saliva IL-5



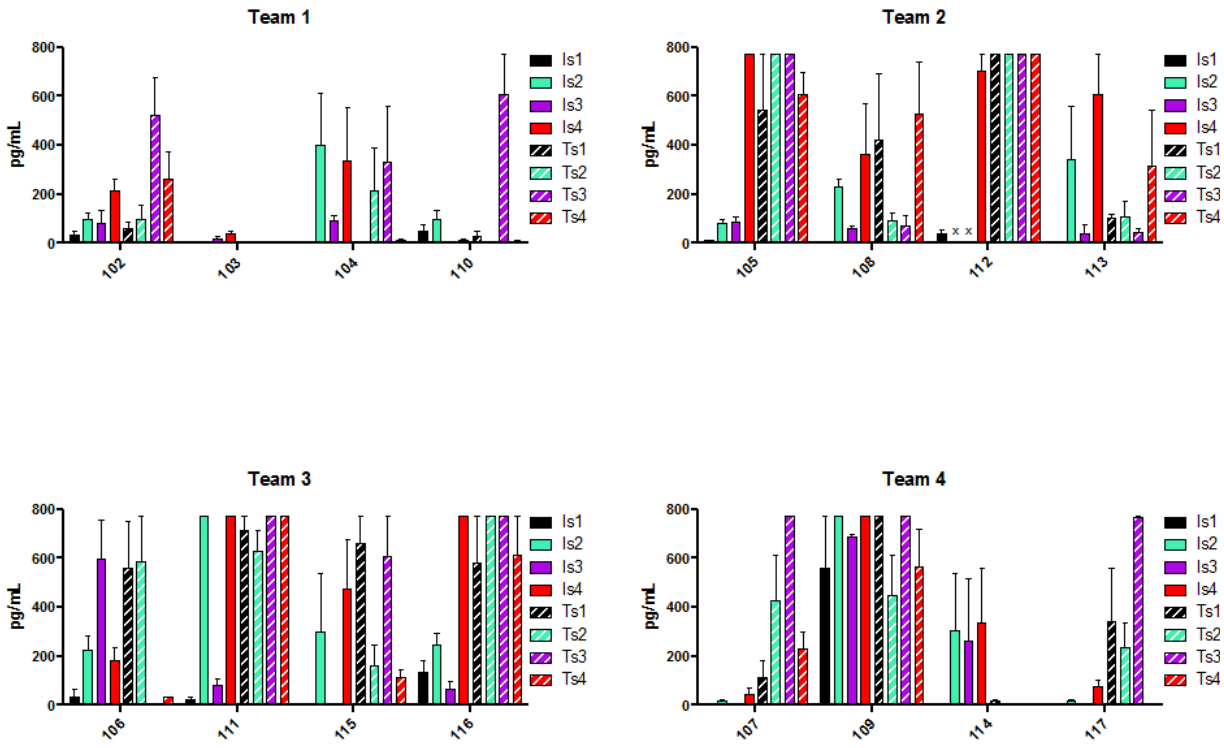
Individual and Team Saliva IFN-g



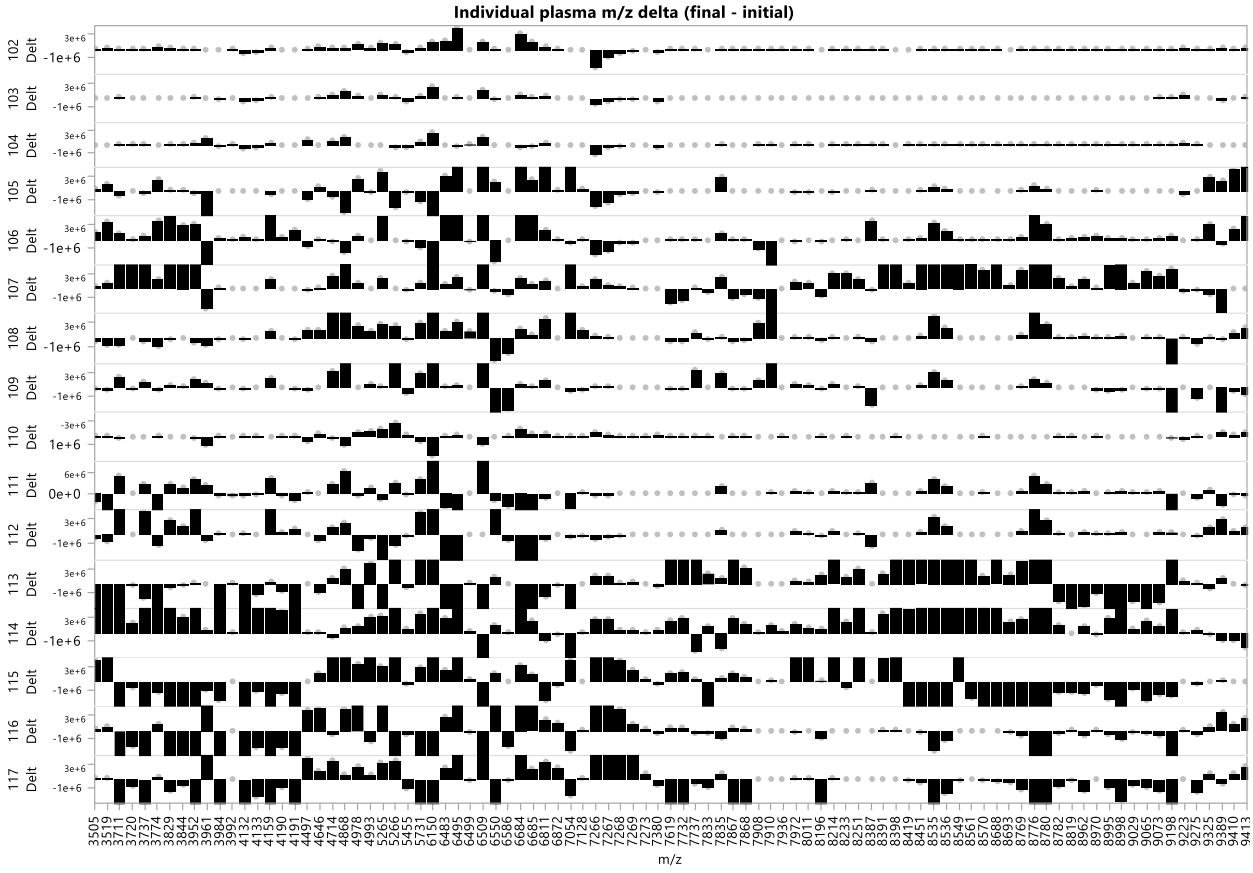
Individual and Team Saliva TNF-a



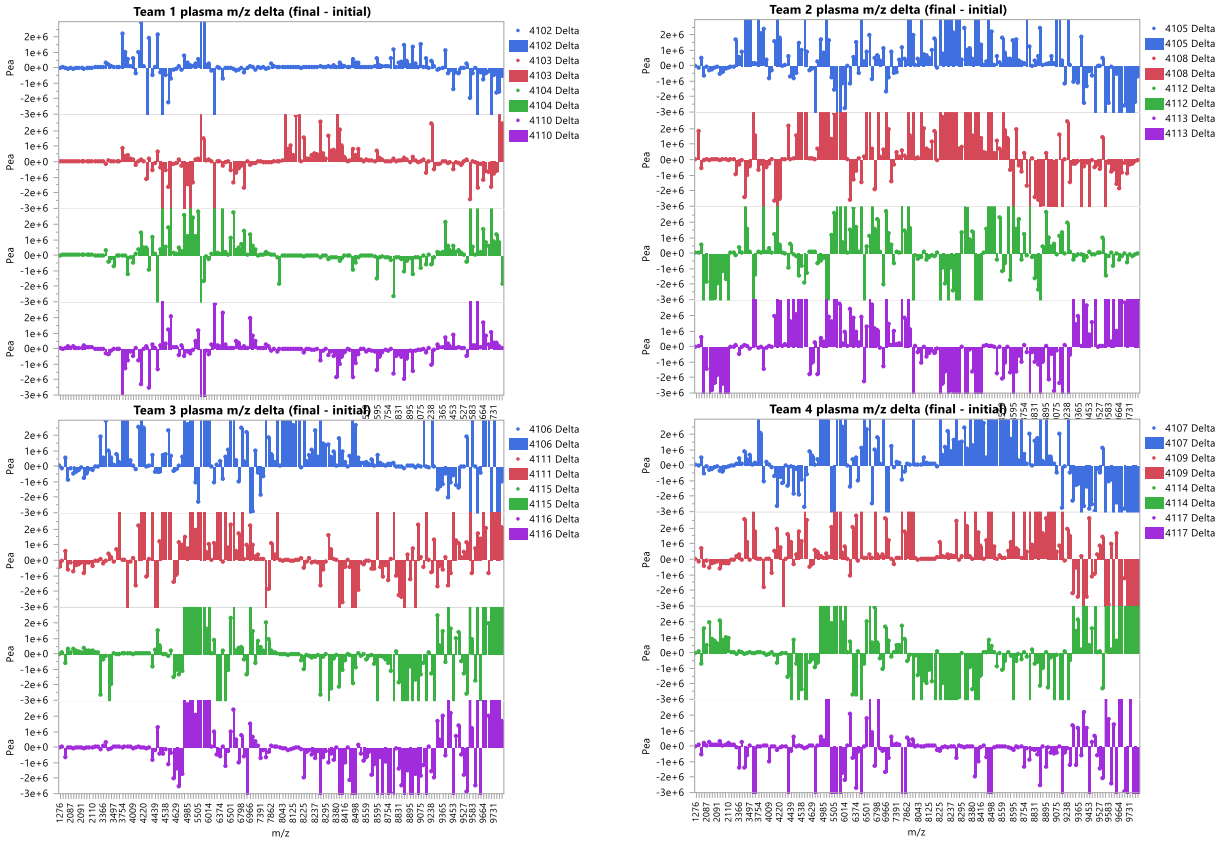
Individual and Team Saliva GM-CSF



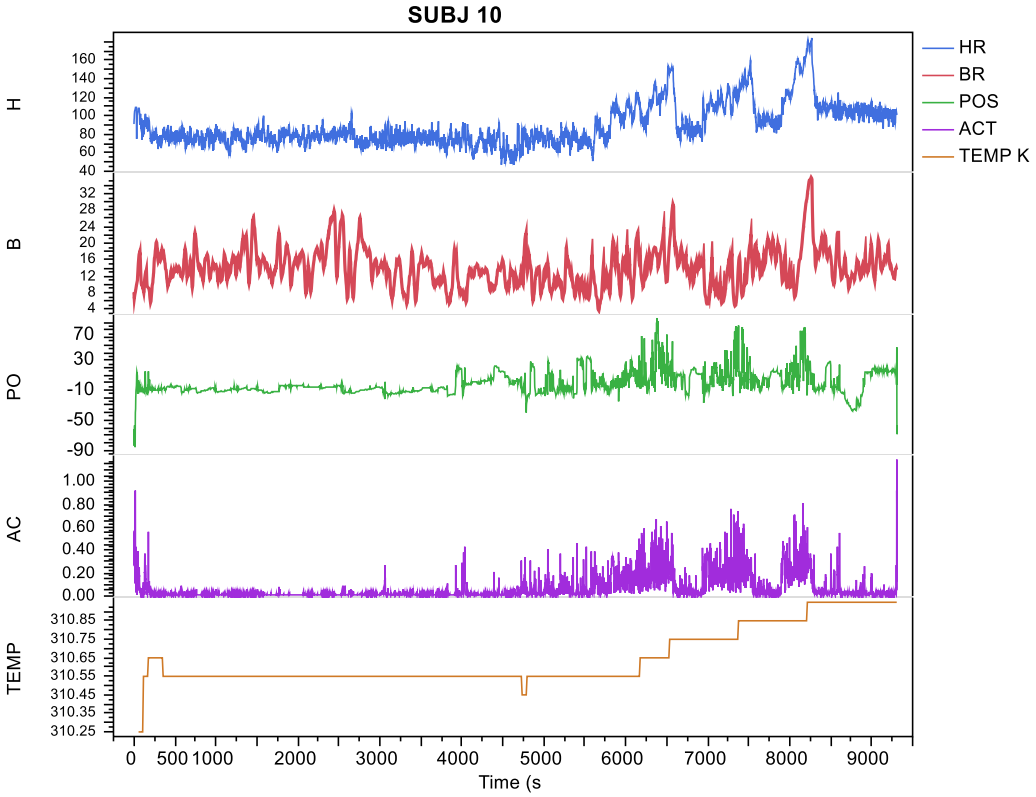
Individual Mass Spectrometry Metabolome

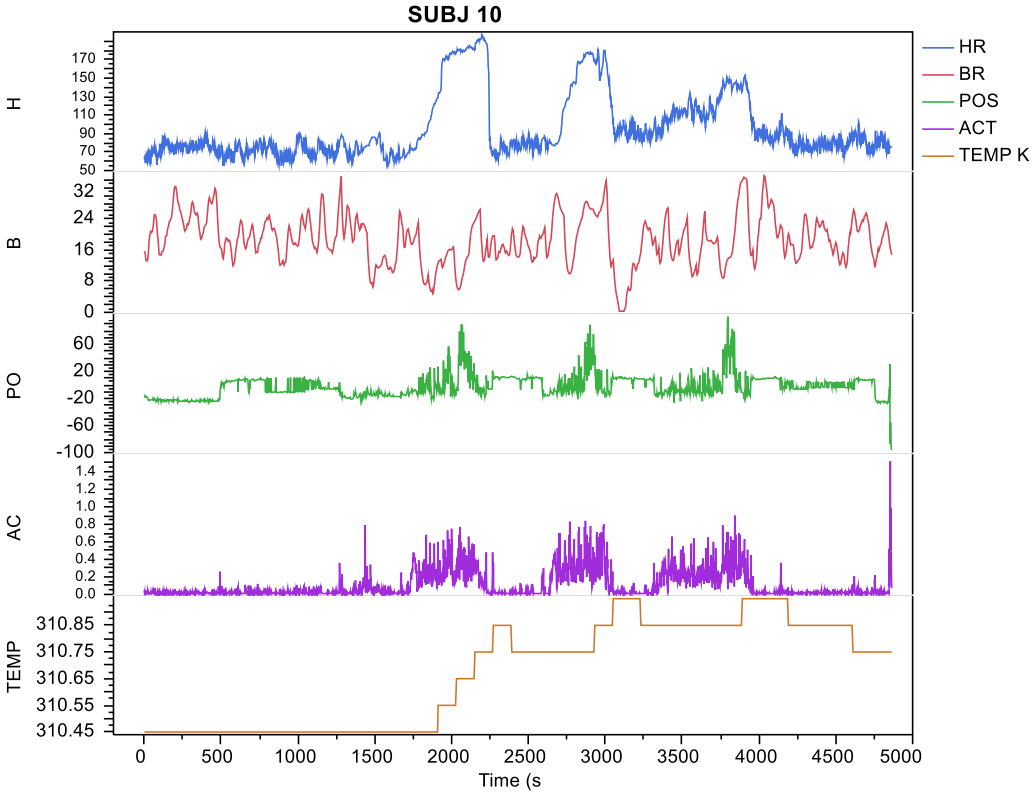


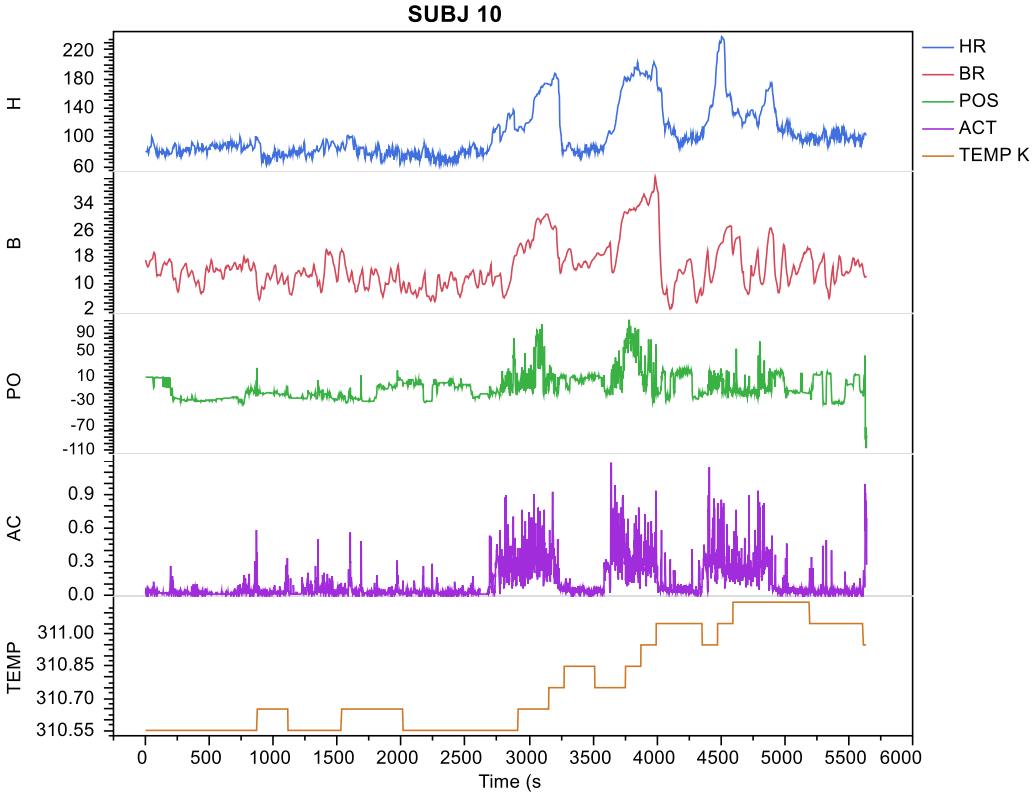
Team Mass Spectrometry Metabolome



EXOGENOUS BIOMARKER DATA FROM INDIVIDUAL EXPERIMENTS



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H
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PO
AC
TEMP
HR
BR
POS
ACT
TEMP K
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100
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18
10
2
90
50
10
-30
-70
-110
0.9
0.6
0.3
0.0
311.00
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310.70
310.55
0
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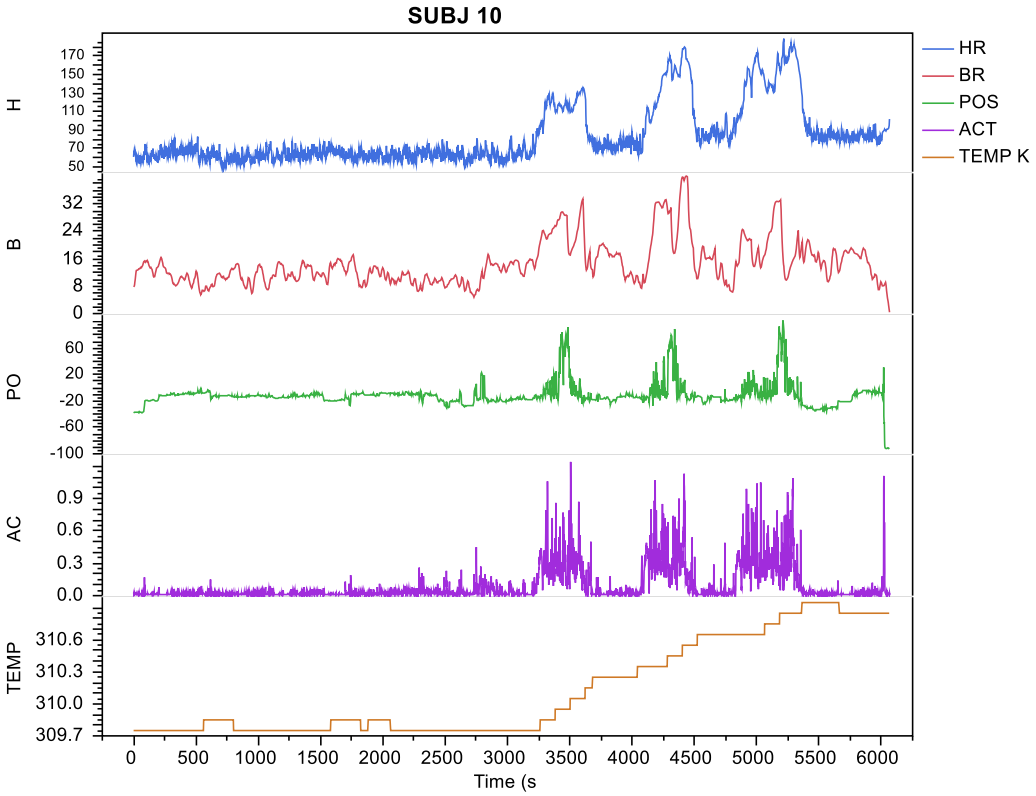
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Time (s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ACT
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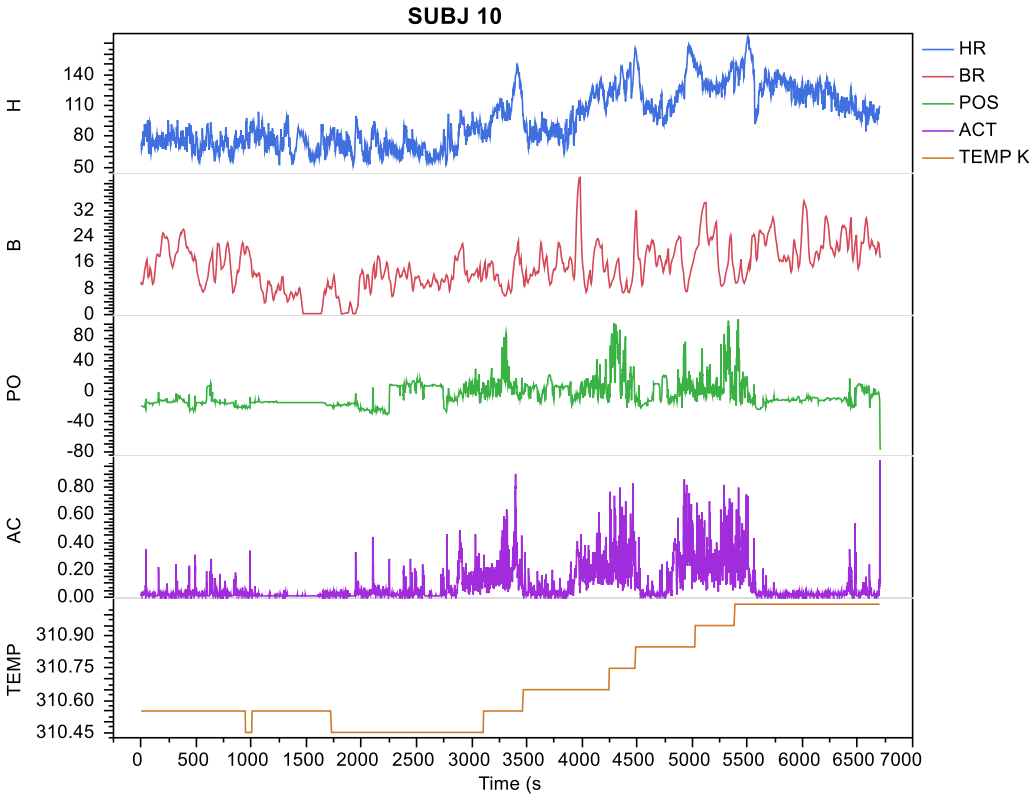
5500
6000
Time (s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ACT
TEMP K
H
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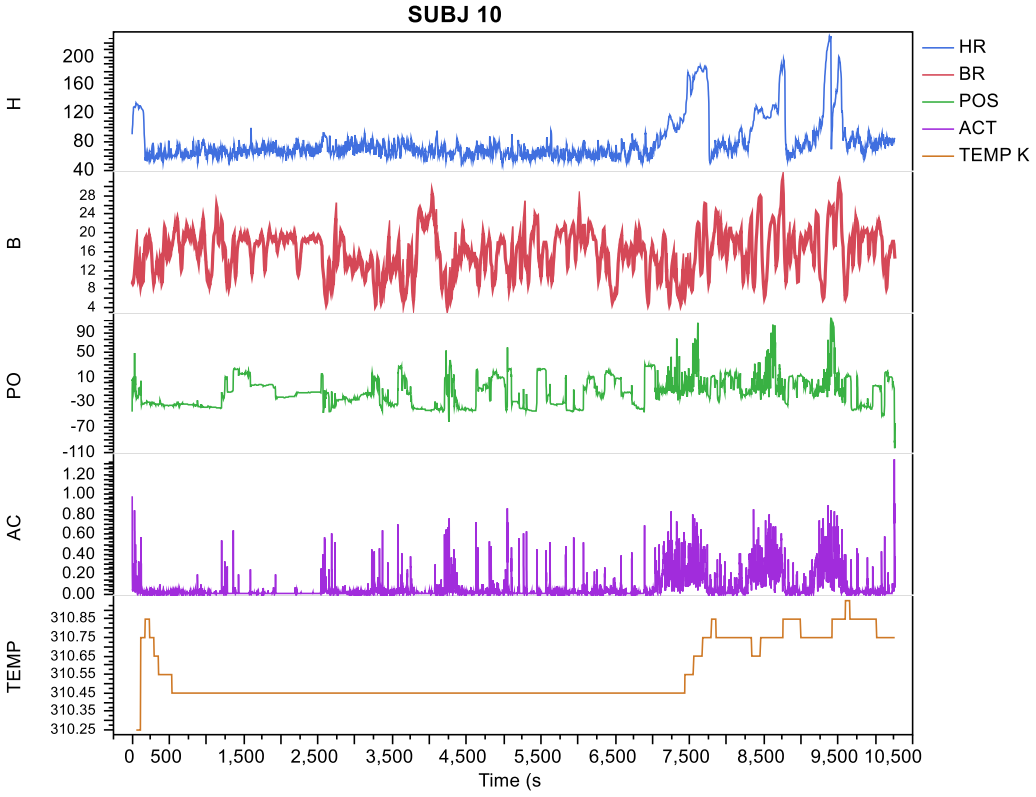
PO
AC
TEMP
Time (s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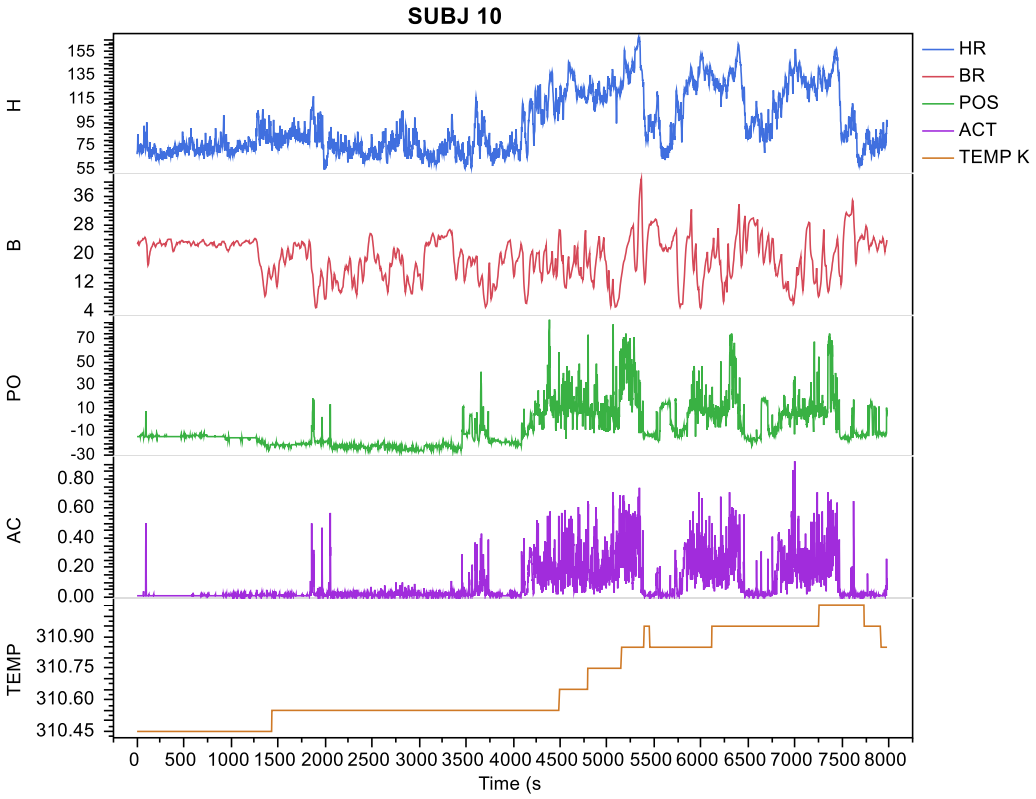
TEMP
Time (s


SUBJ 10
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PO
AC
TEMP
HR
BR
POS
ACT
TEMP K
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95
75
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4
70
50
30
10
-10
-30
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0.60
0.40
0.20
0.00
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310.75
310.60
310.45
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7500
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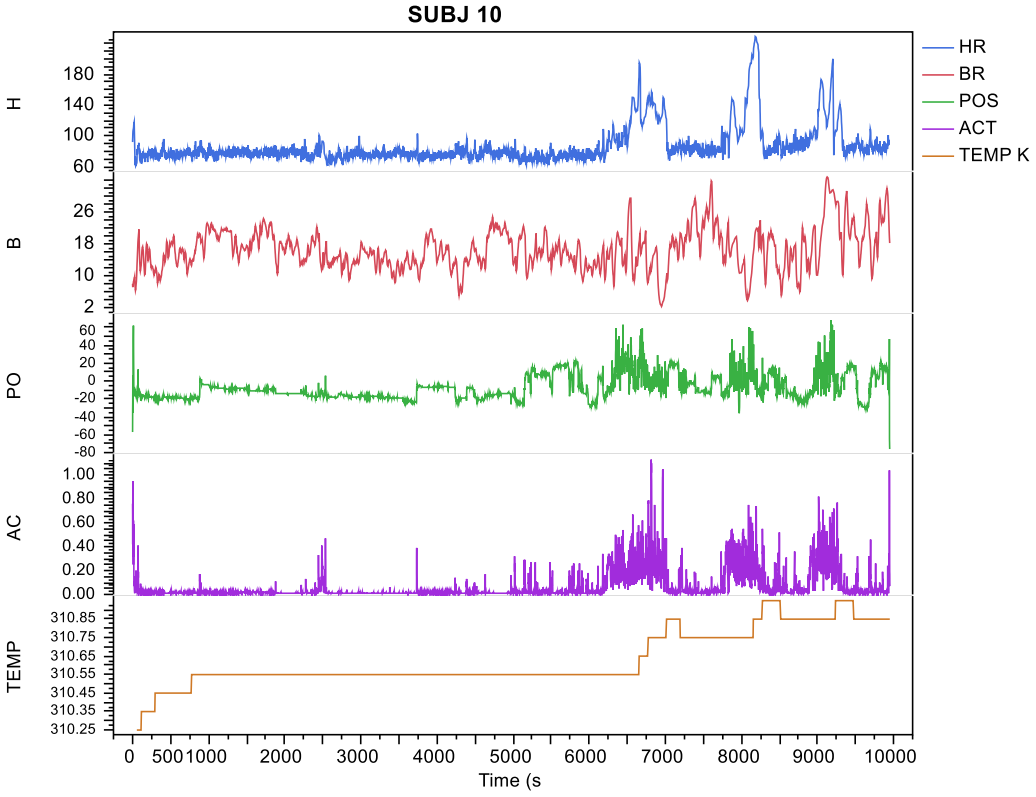
Time (s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TEMP K
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0.80
0.60
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0.20
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5000
6000
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9000
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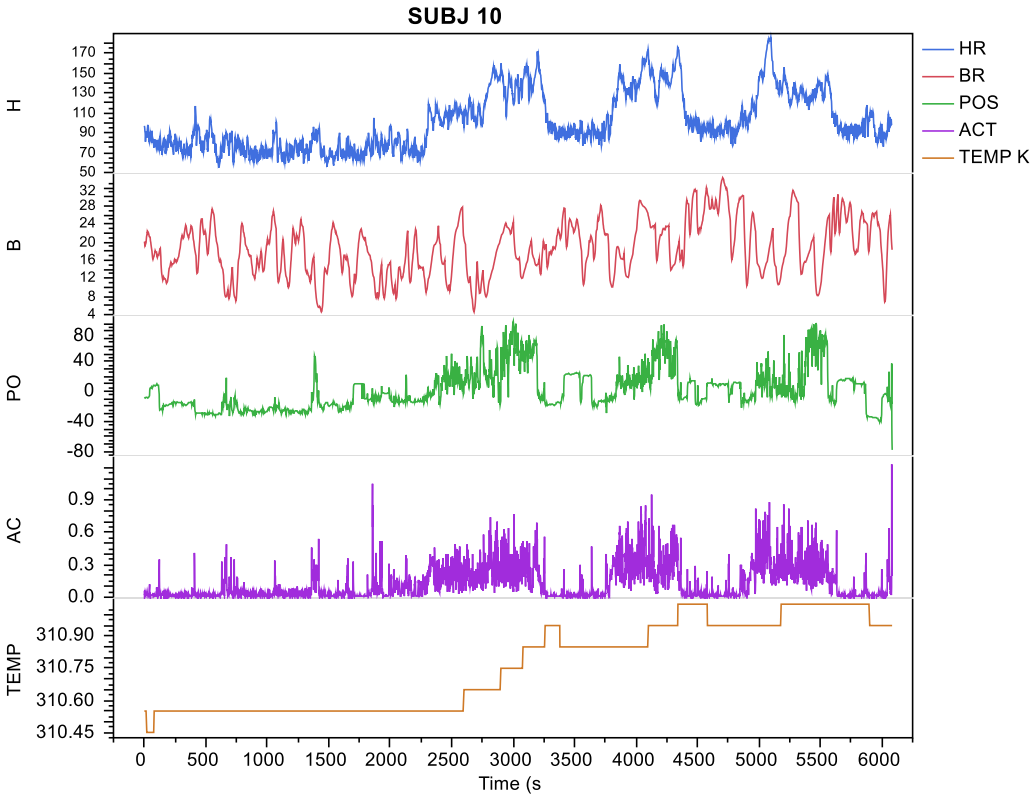
Time (s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POS
ACT
TEMP K
H
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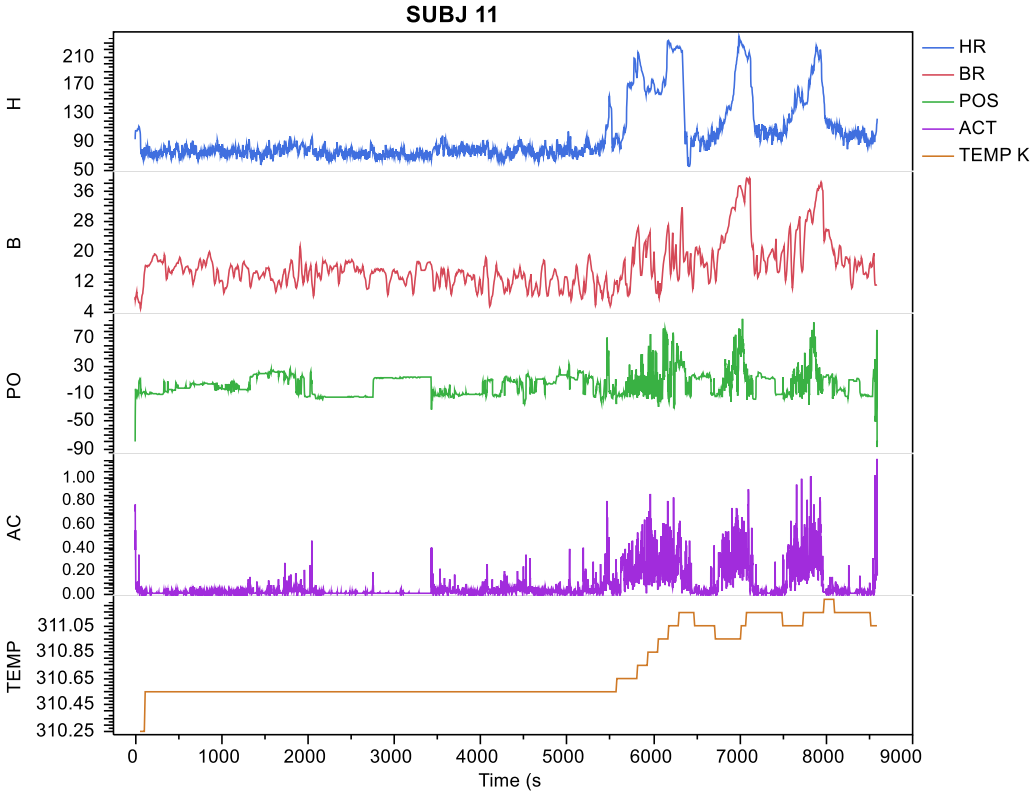
PO
AC
TEMP
Time (s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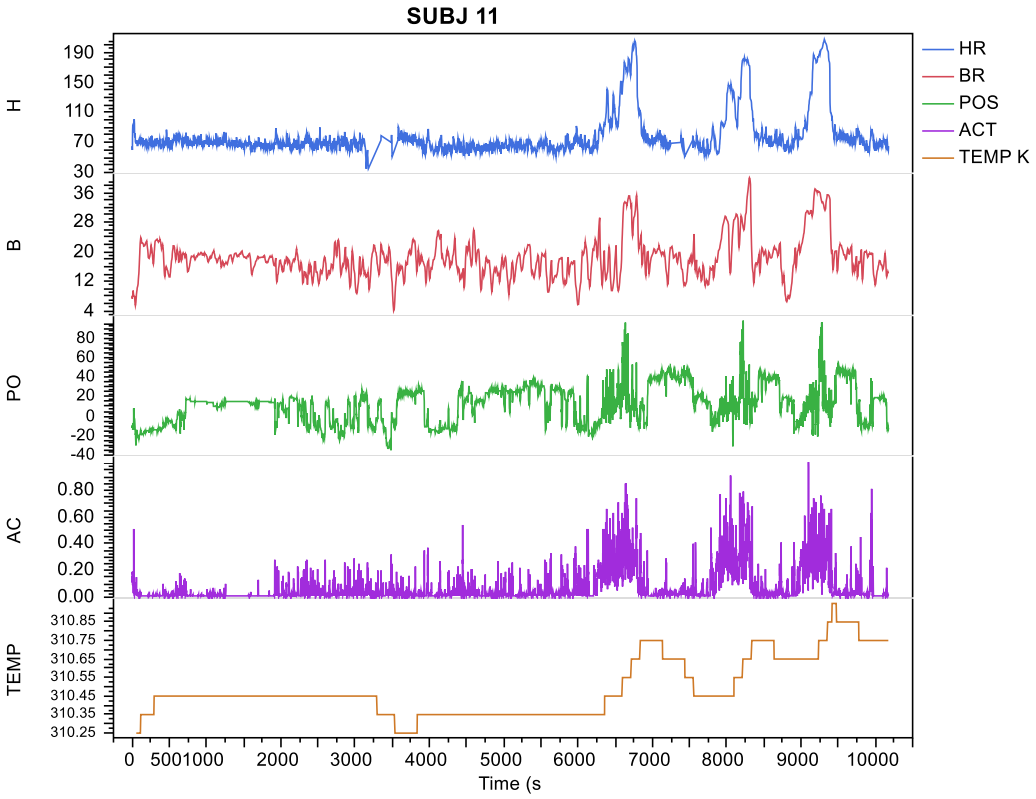
POS
ACT
TEMP K
H
B
PO
AC
TEMP
Time (s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TEMP
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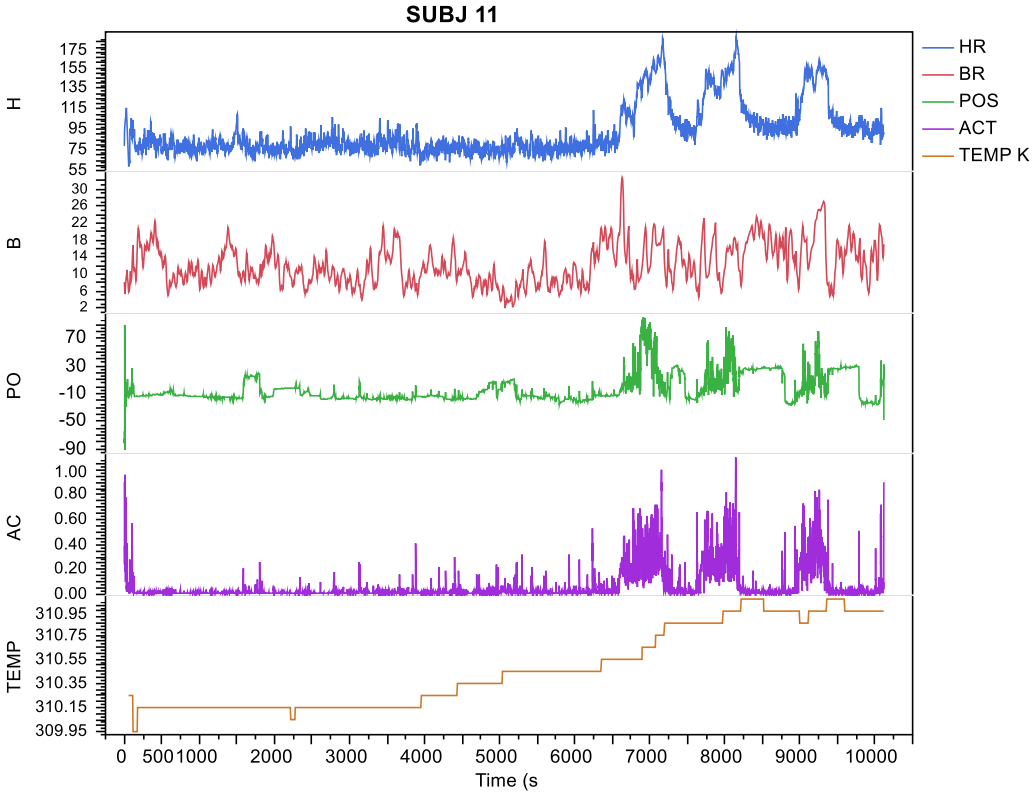
POS
ACT
TEMP K
Time (s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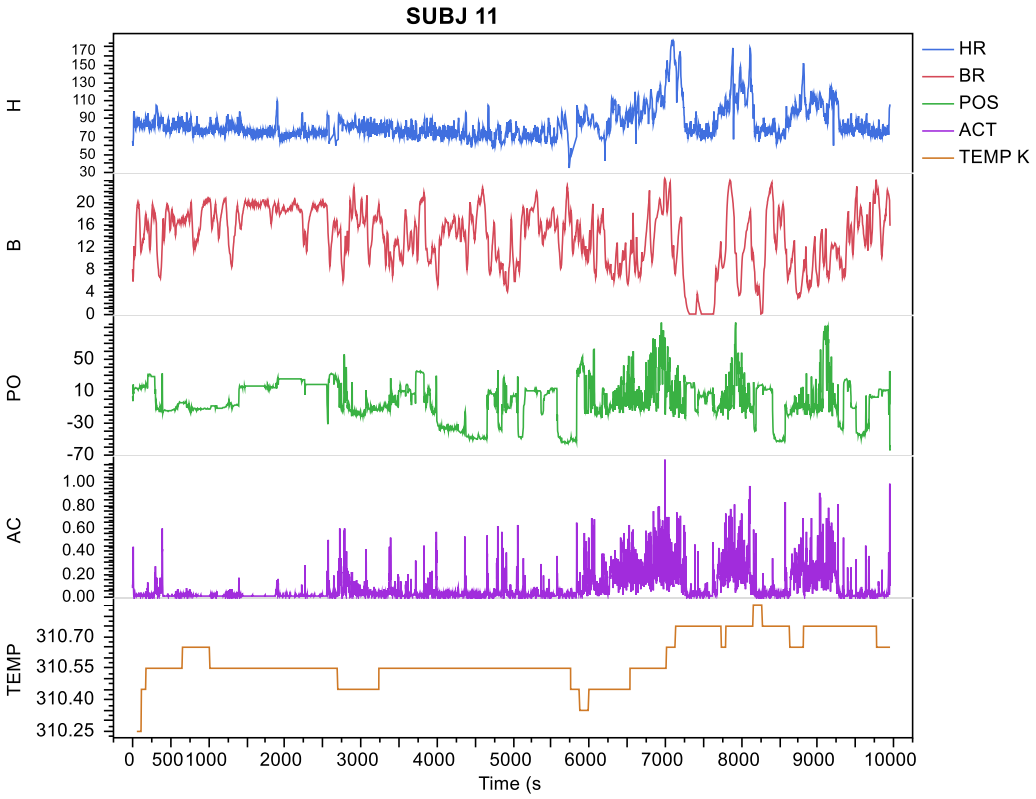
ACT
TEMP K
Time (s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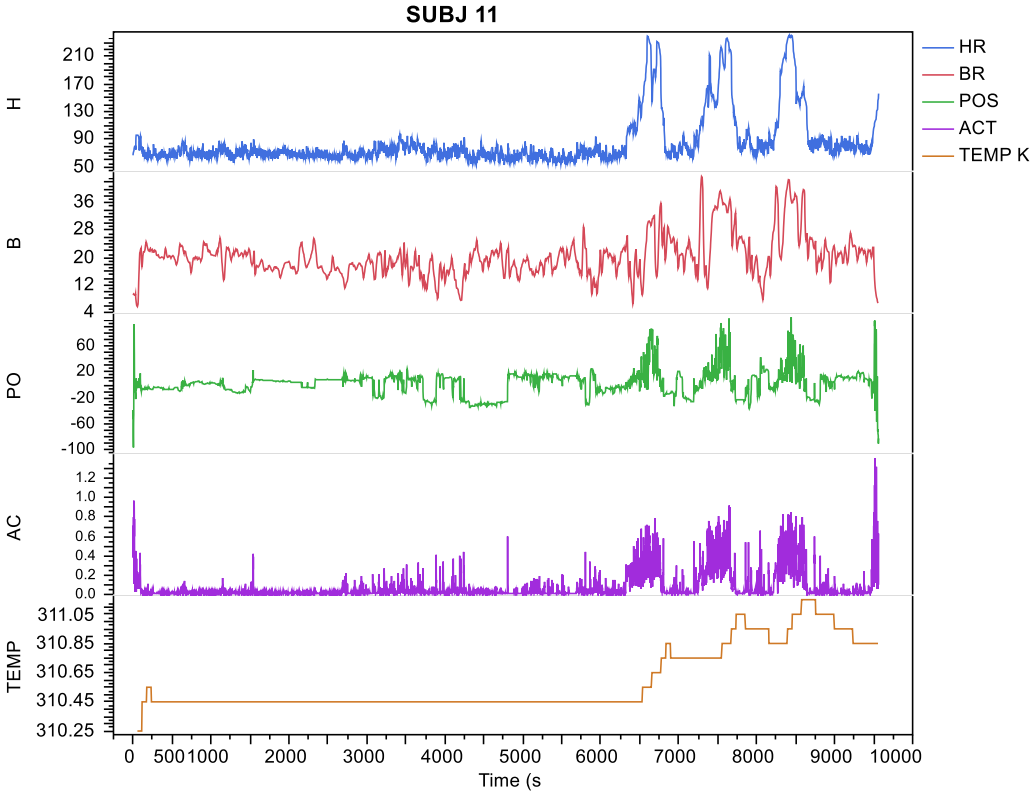
HR
BR
POS
ACT
TEMP K
Time (s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HR
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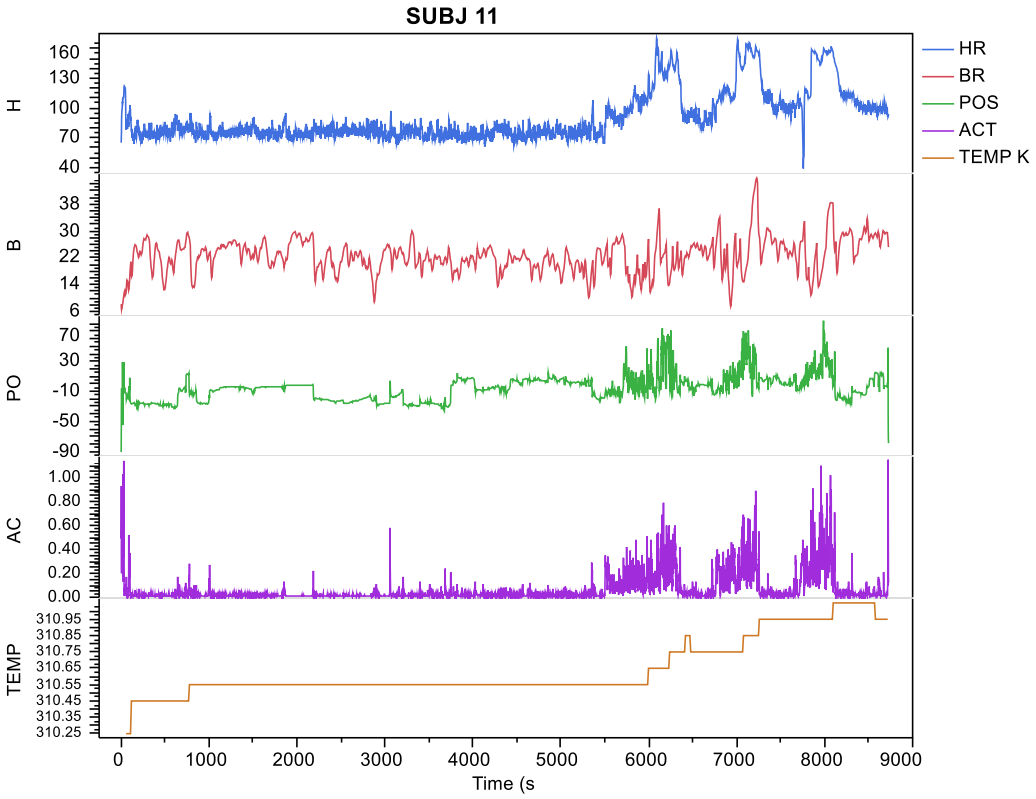
POS
ACT
TEMP K
Time (s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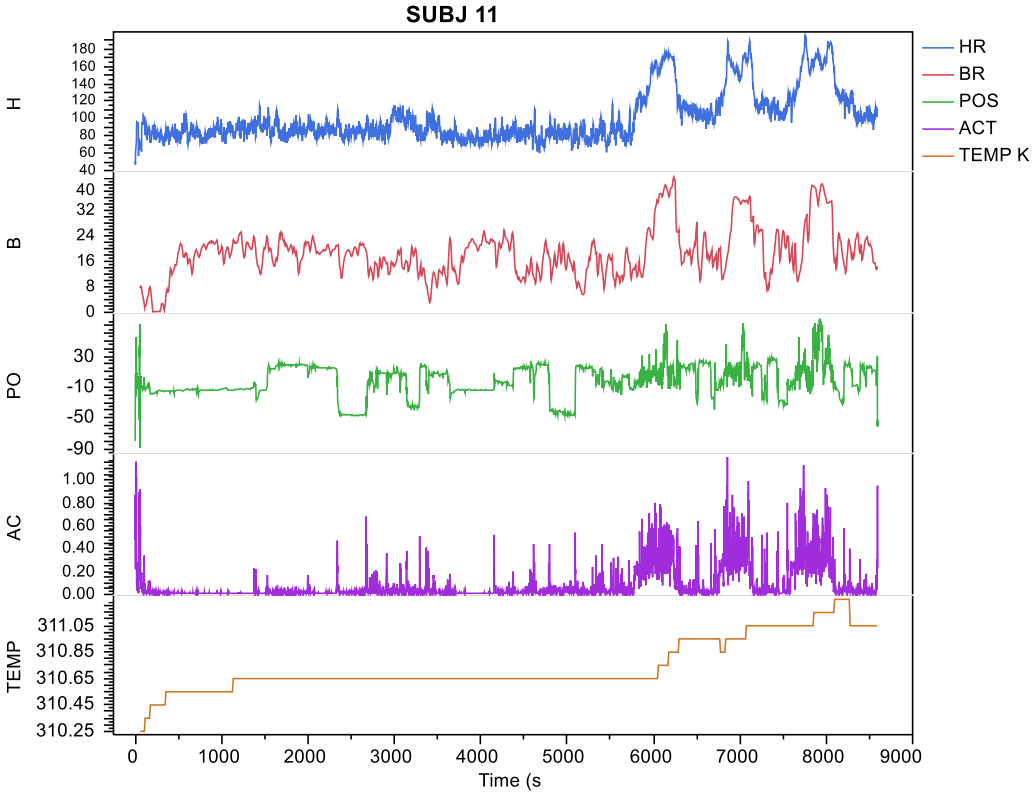
TEMP K
Time (s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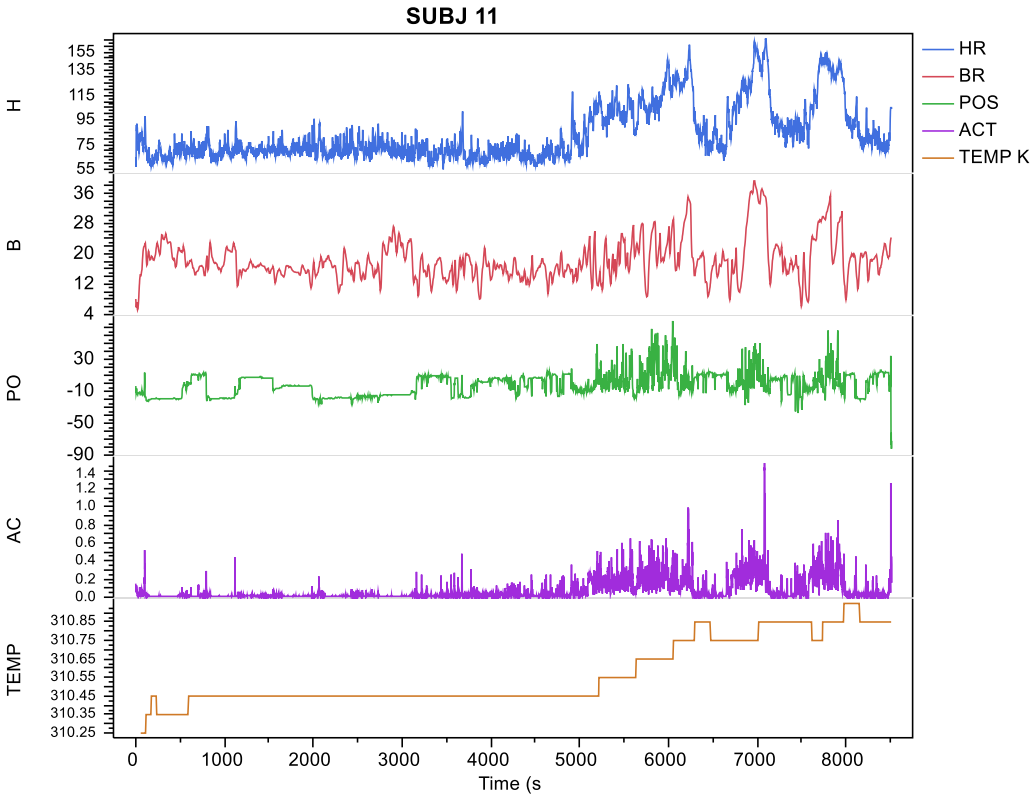
POS
ACT
TEMP K
Time (s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-90
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1.2
1.0
0.8
0.6
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0.2
0.0
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310.75
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310.45
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1000
2000
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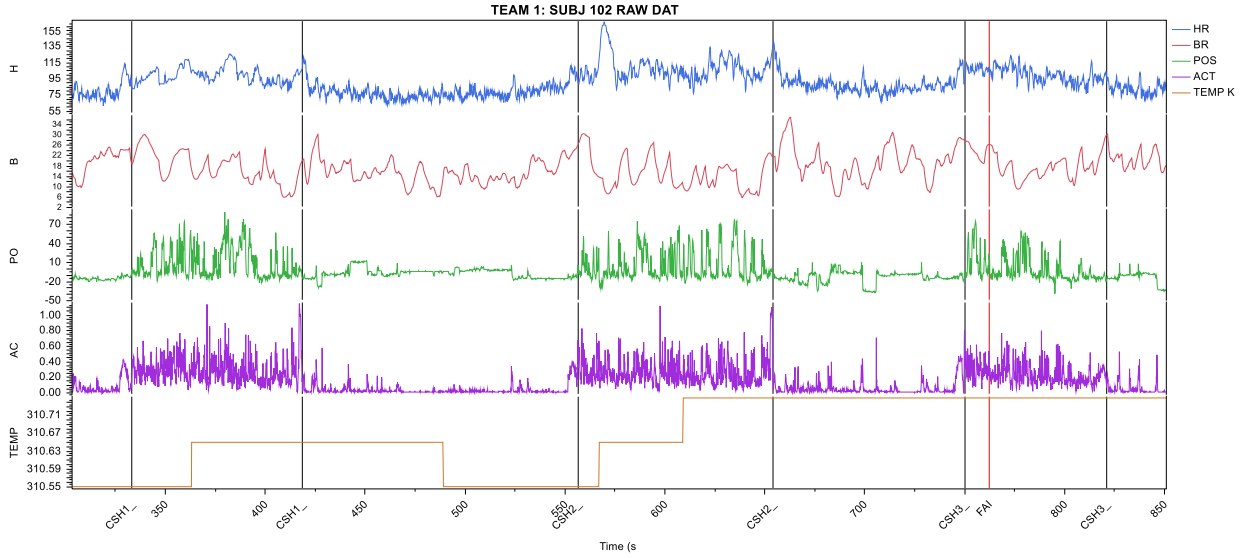
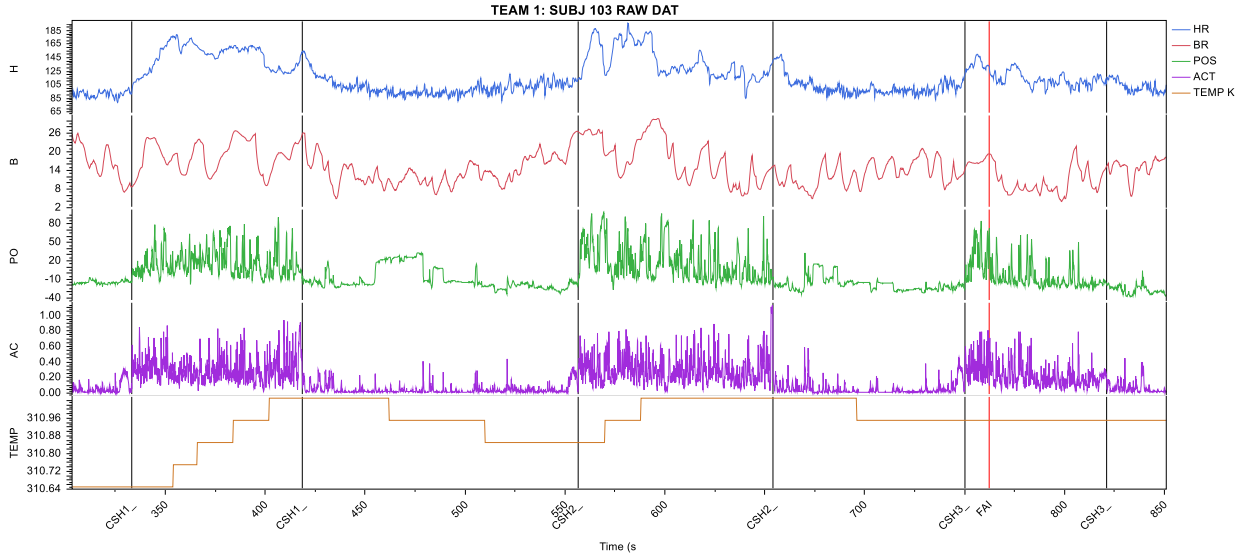
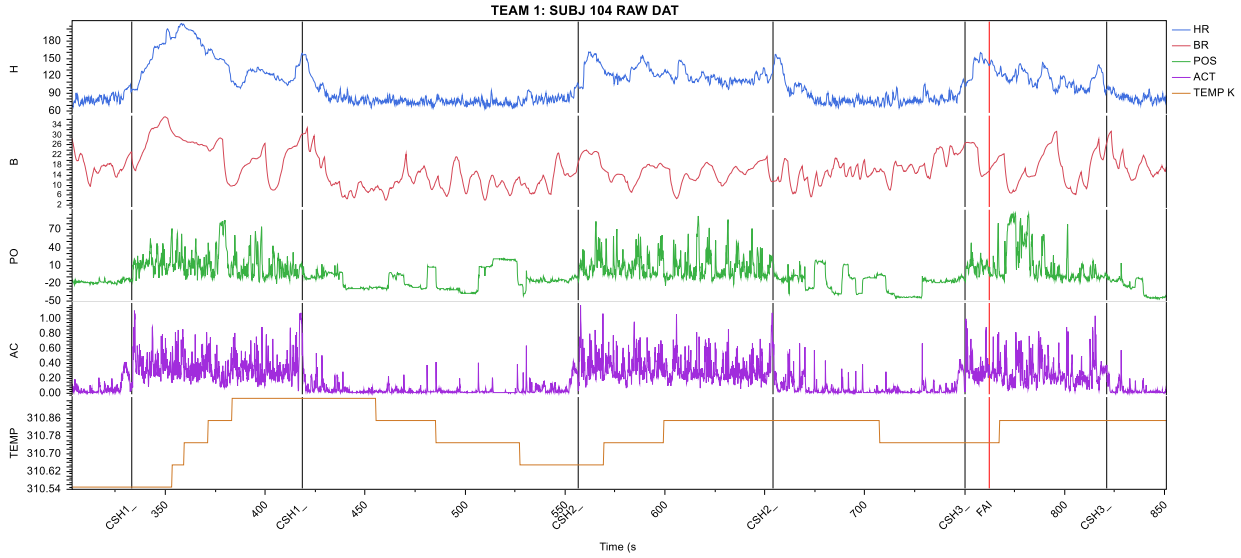
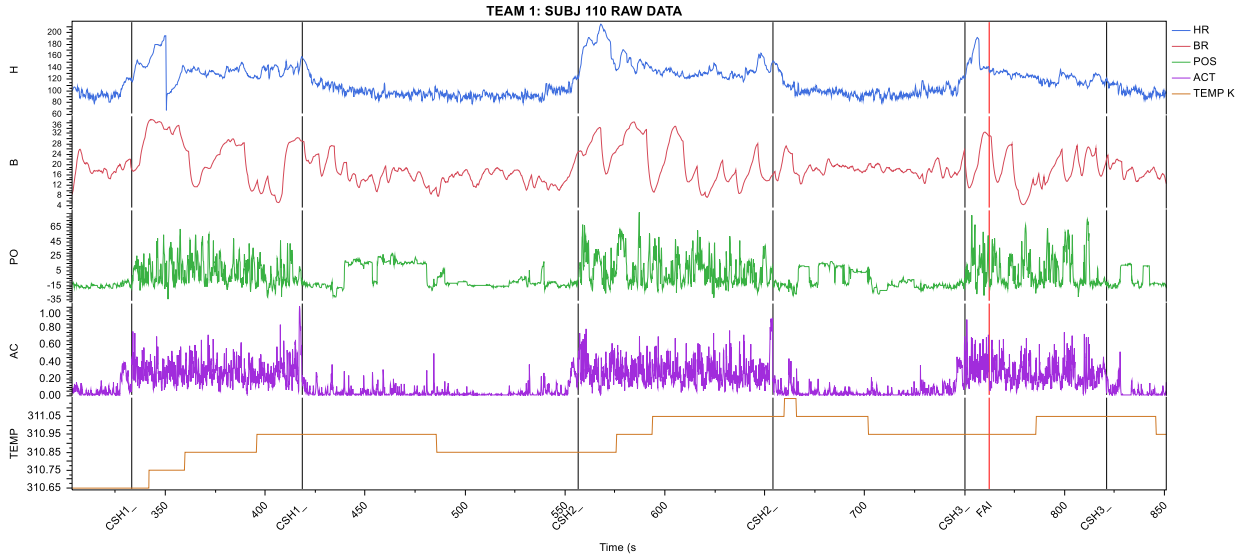
4000
5000
6000
7000
8000
Time (s

EXOGENOUS BIOMARKER DATA FROM TEAM EXPERIMENTS






TEAM 1: SUBJ 104 RAW DAT
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s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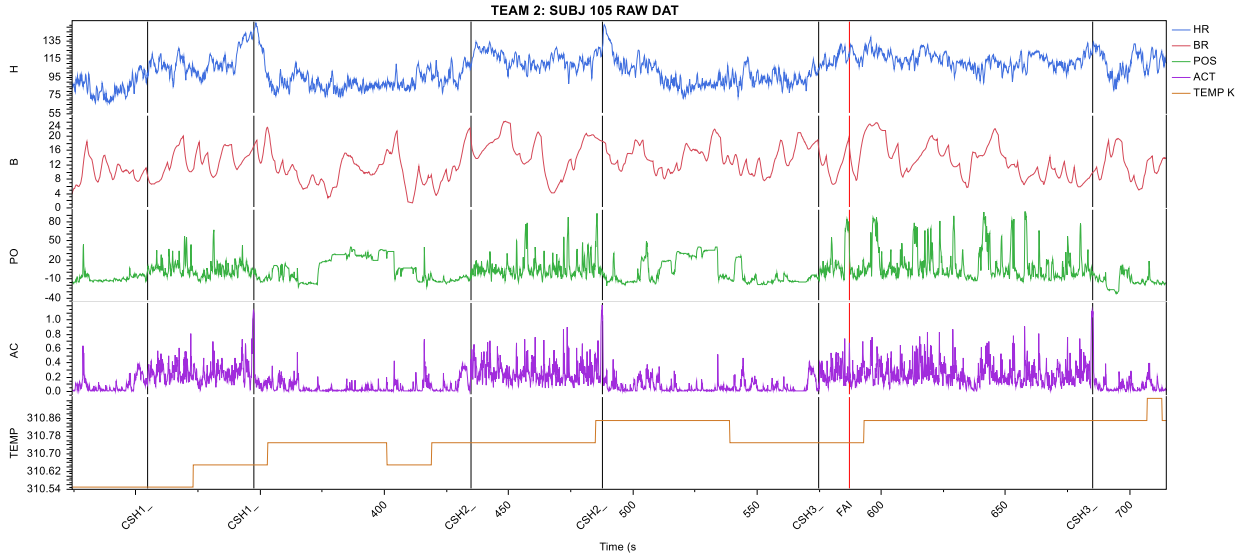
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s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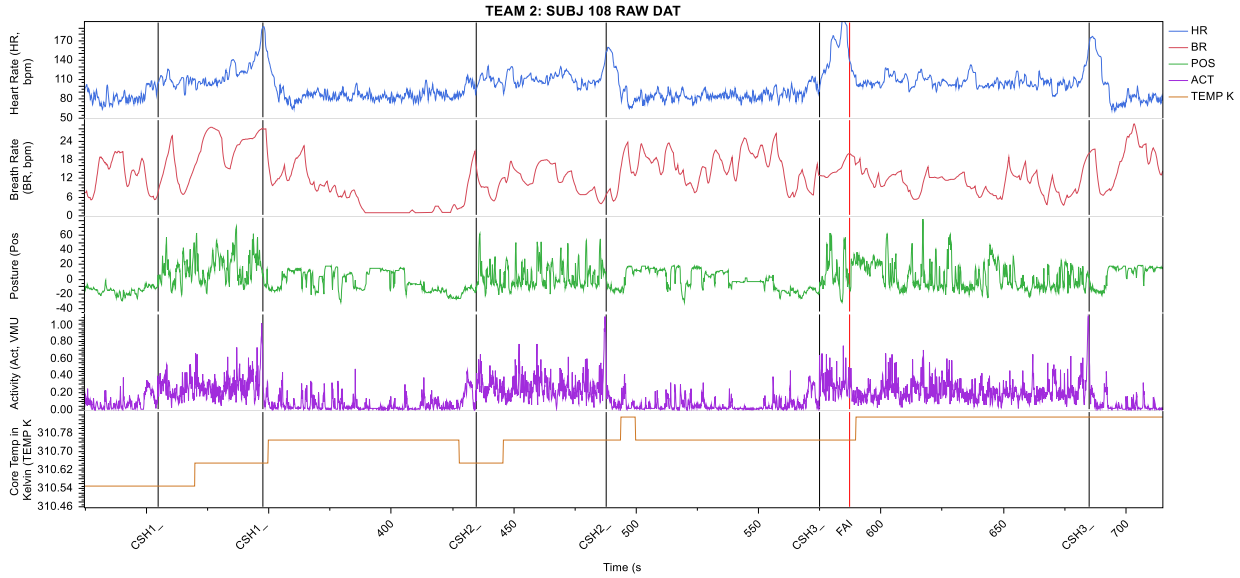
H
B
PO
AC
TEMP
HR
BR
POS
ACT
TEMP K
CSH1_
CSH1_
400
CSH2_
450
CSH2_
500
550
CSH3_
FAI
600
650
CSH3_
700
Time (s


TEAM 2: SUBJ 108 RAW DAT
Heart Rate (HR, bpm)
Breath Rate (BR, bpm)
Posture (Pos
Activity (Act, VMU
Core Temp in Kelvin (TEMP K
HR
BR
POS
ACT
TEMP K
CSH1_
CSH1_
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CSH2_
450
CSH2_
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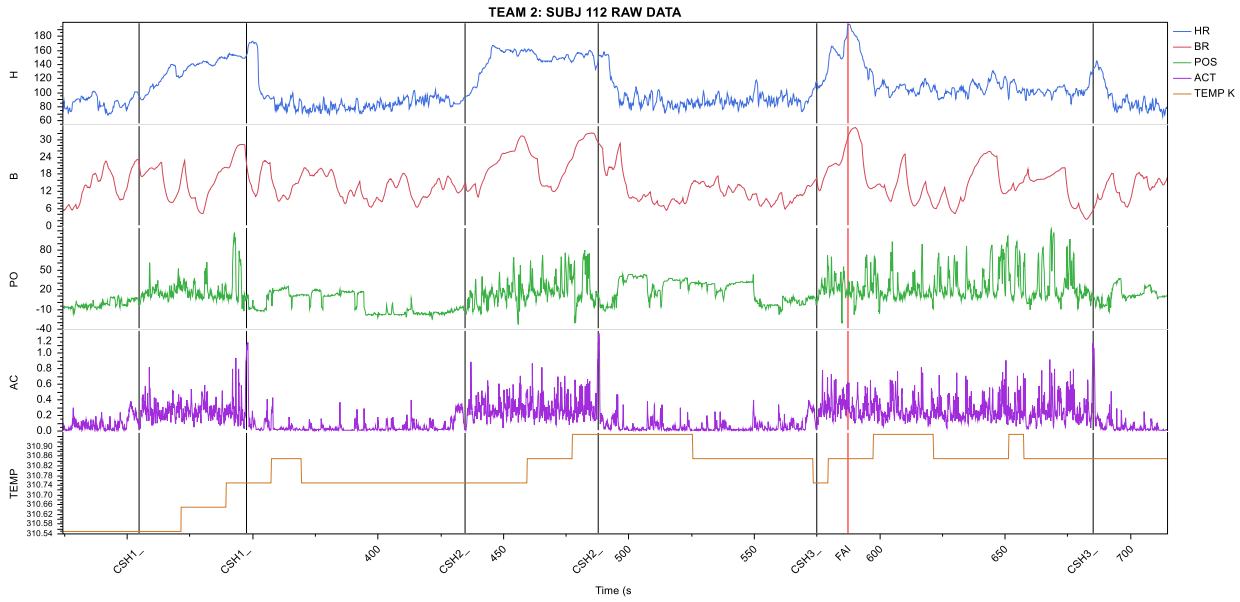
550
CSH3_
FAI
600
650
CSH3_
700
Time (s


TEAM 2: SUBJ 112 RAW DATA
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
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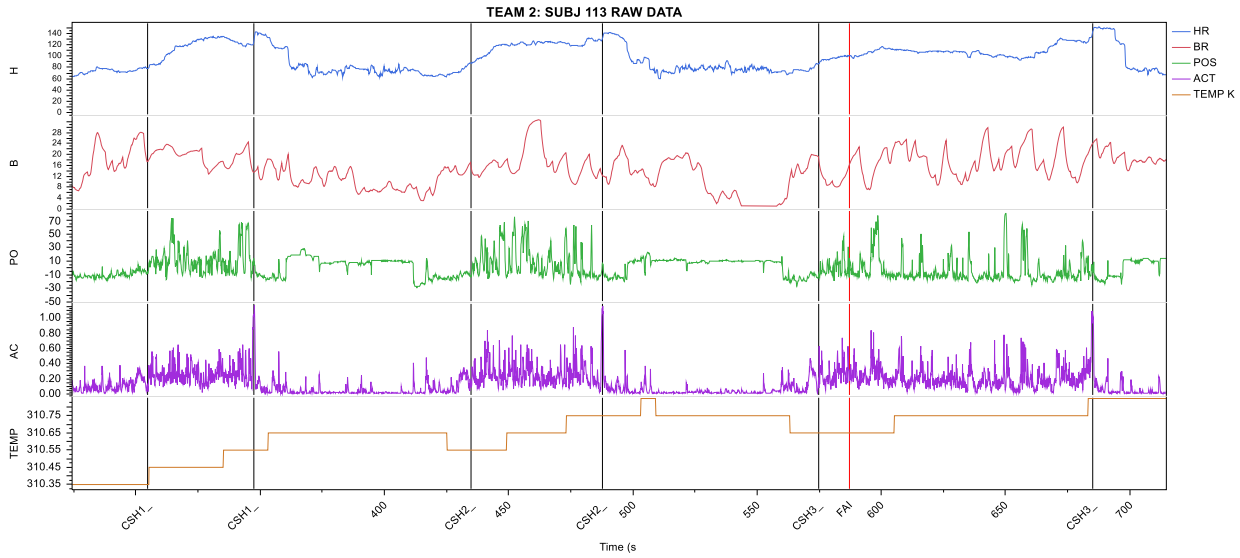
CSH2_
450
CSH2_
500
550
CSH3_
FAI
600
650
CSH3_
700
Time (s


TEAM 2: SUBJ 113 RAW DATA
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
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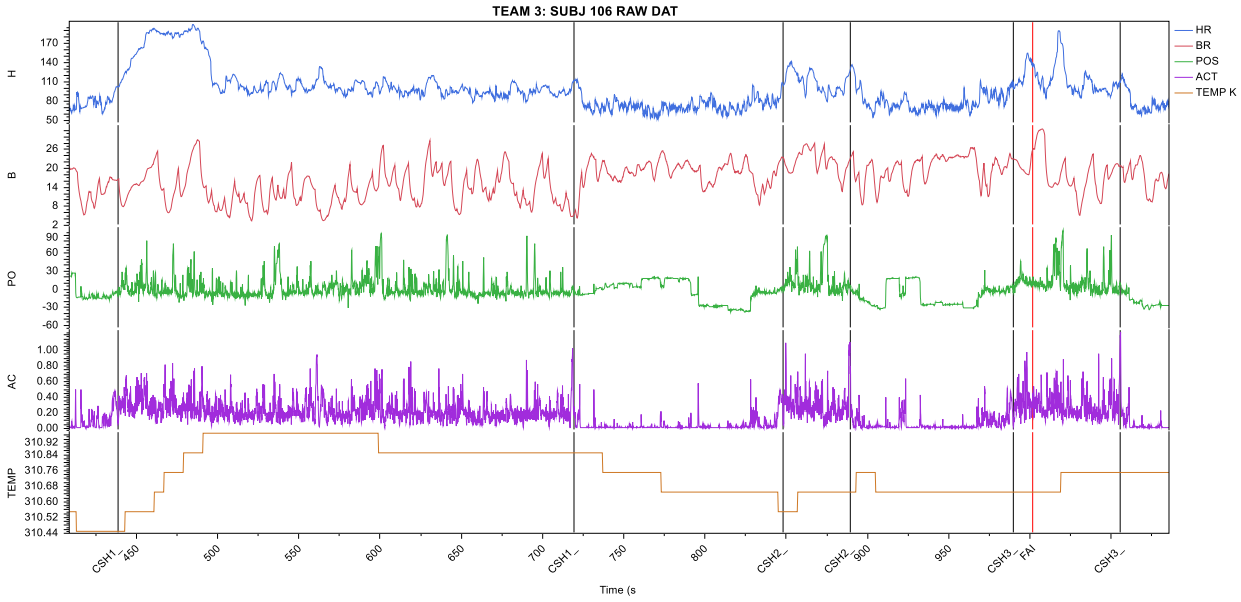
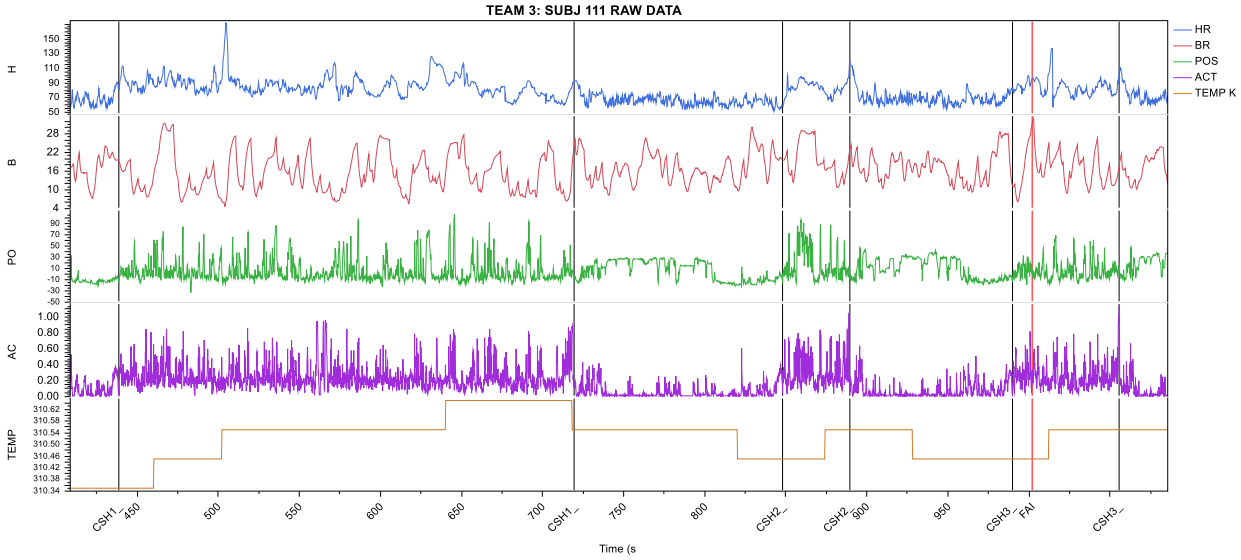
CSH2_
450
CSH2_
500
550
CSH3_
FAI
600
650
CSH3_
700
Time (s


TEAM 3: SUBJ 106 RAW DAT
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s


TEAM 3: SUBJ 111 RAW DATA
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BR
POS
ACT
TEMP K
H
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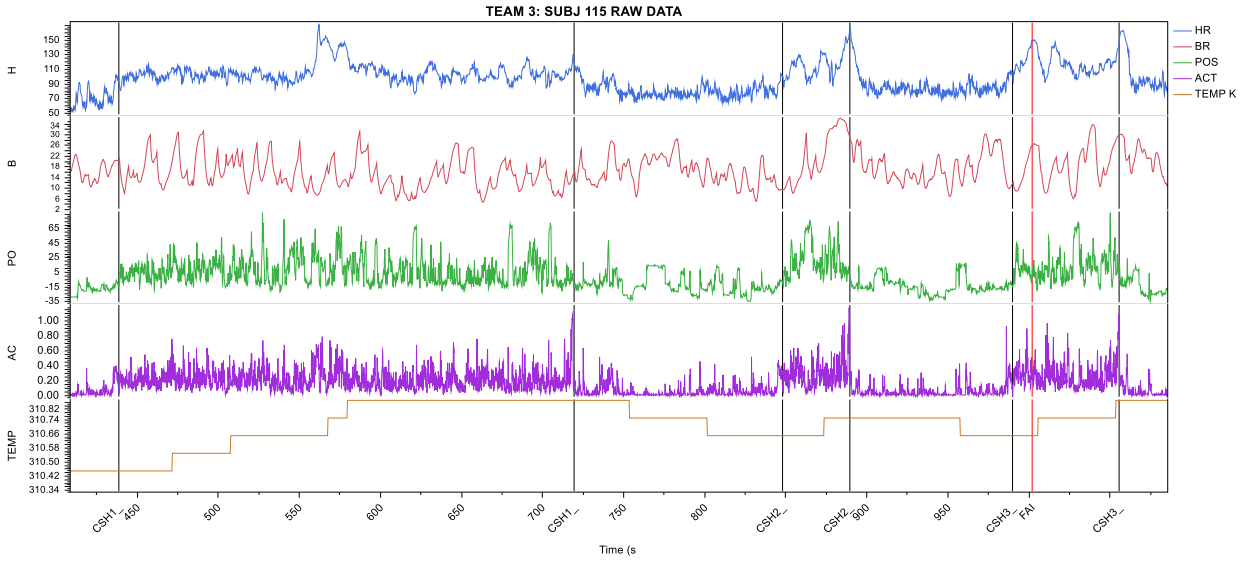
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s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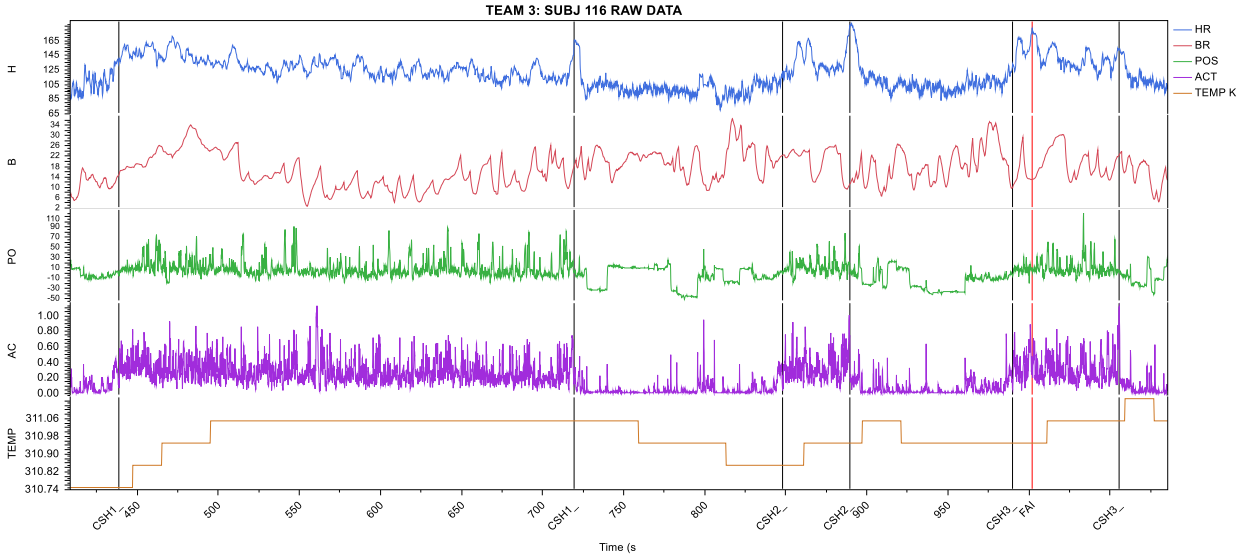
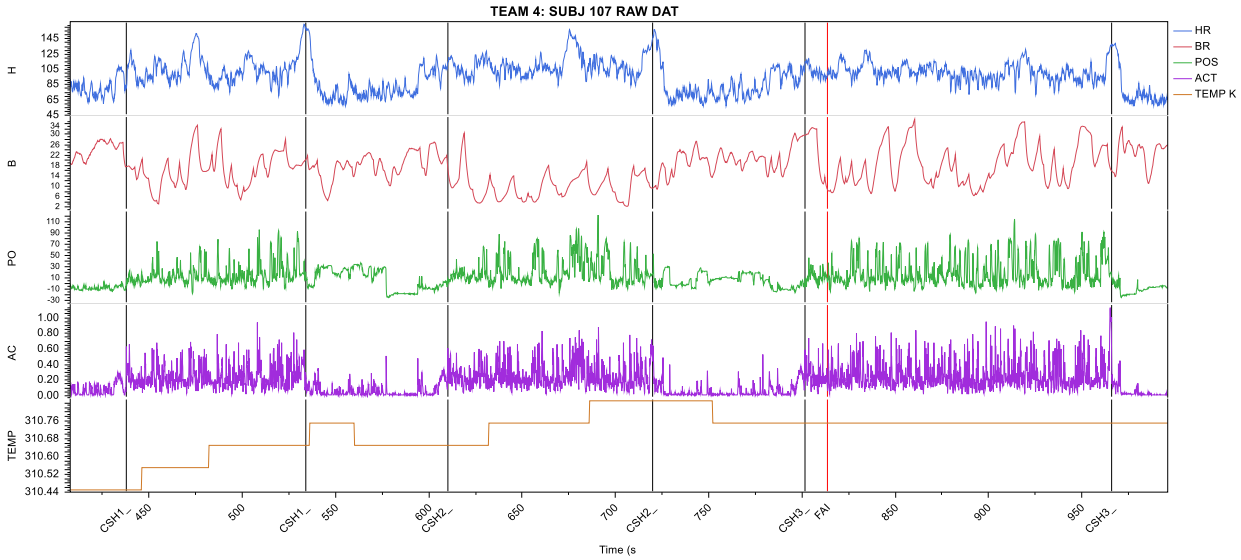
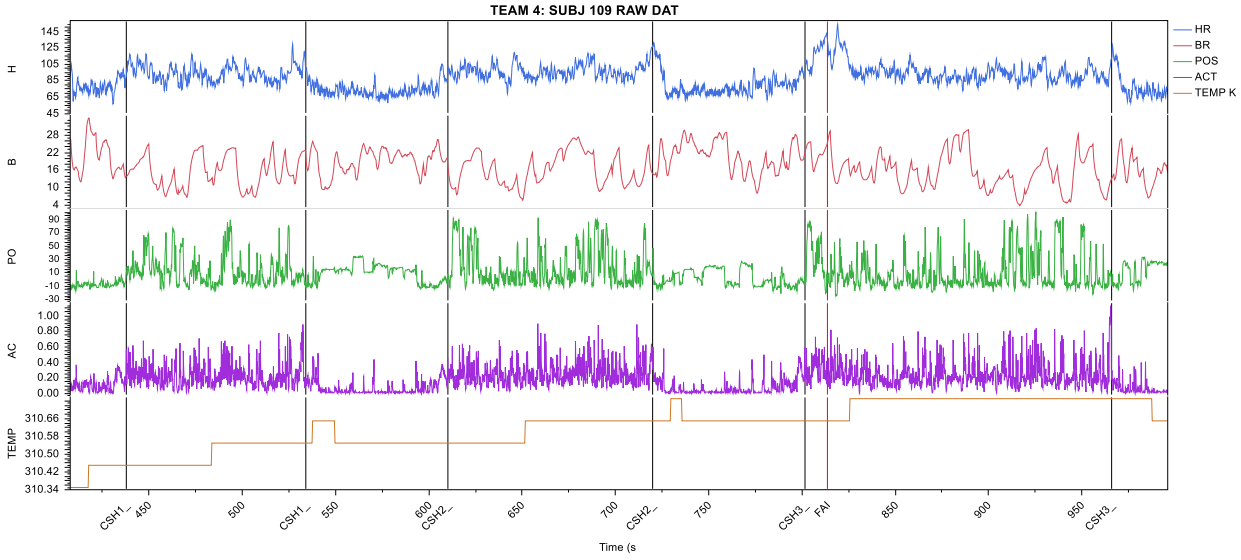
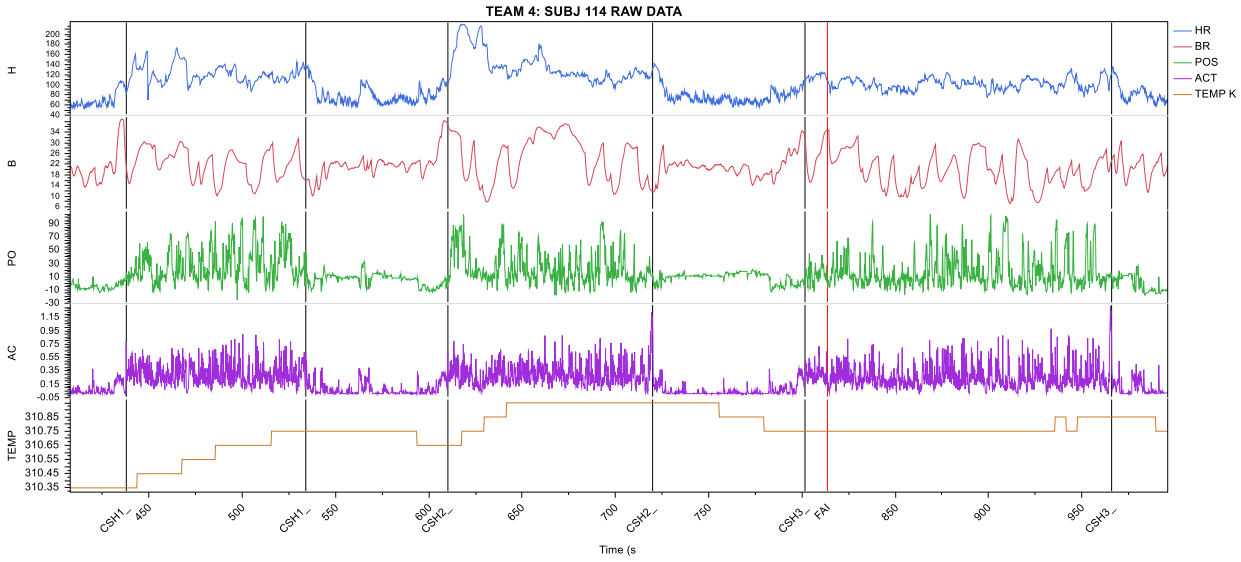
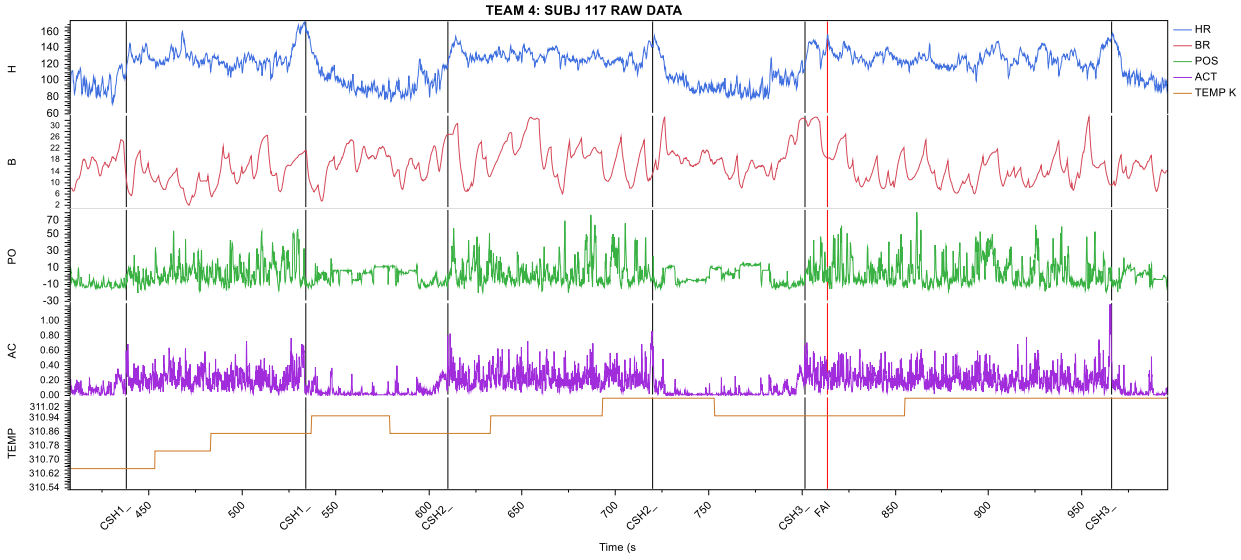
PO
AC
TEMP
HR
BR
POS
ACT
TEMP K
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s


TEAM 3: SUBJ 116 RAW DATA
H
B
PO
AC
TEMP
HR
BR
POS
ACT
TEMP K
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s

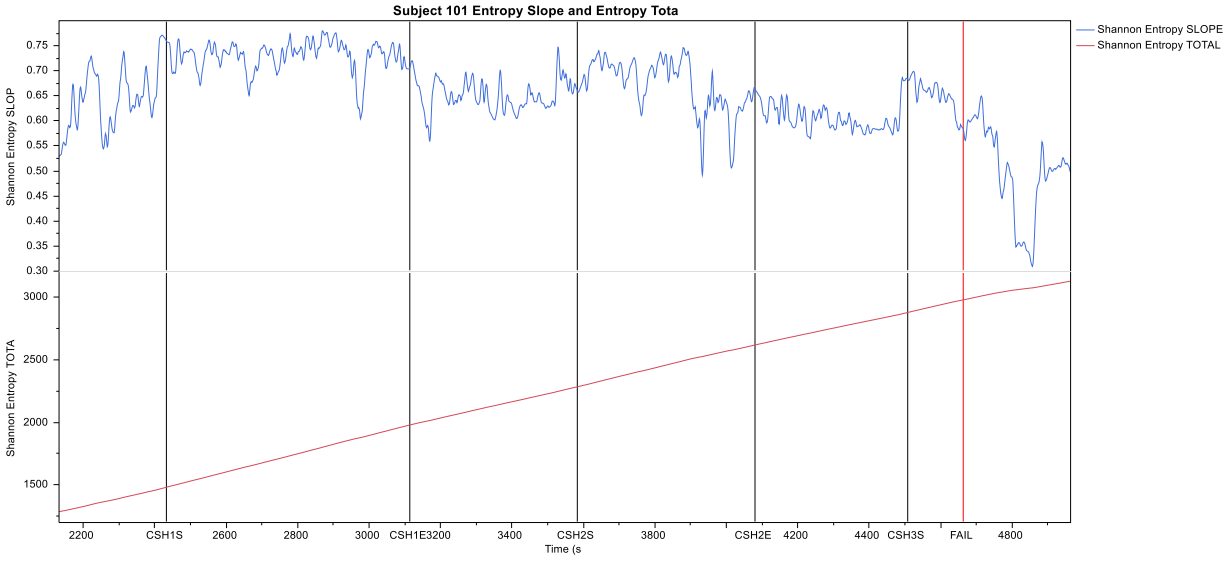

TEAM 4: SUBJ 107 RAW DAT
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
CSH3_
FAI
Time (s

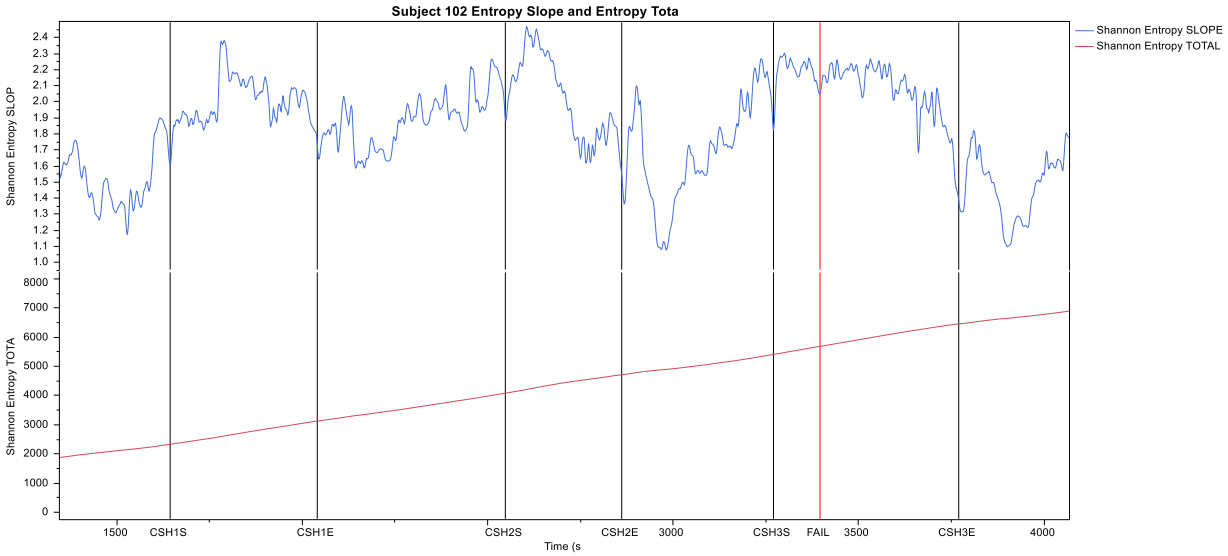

TEAM 4: SUBJ 109 RAW DAT
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
CSH3_
FAI
Time (s

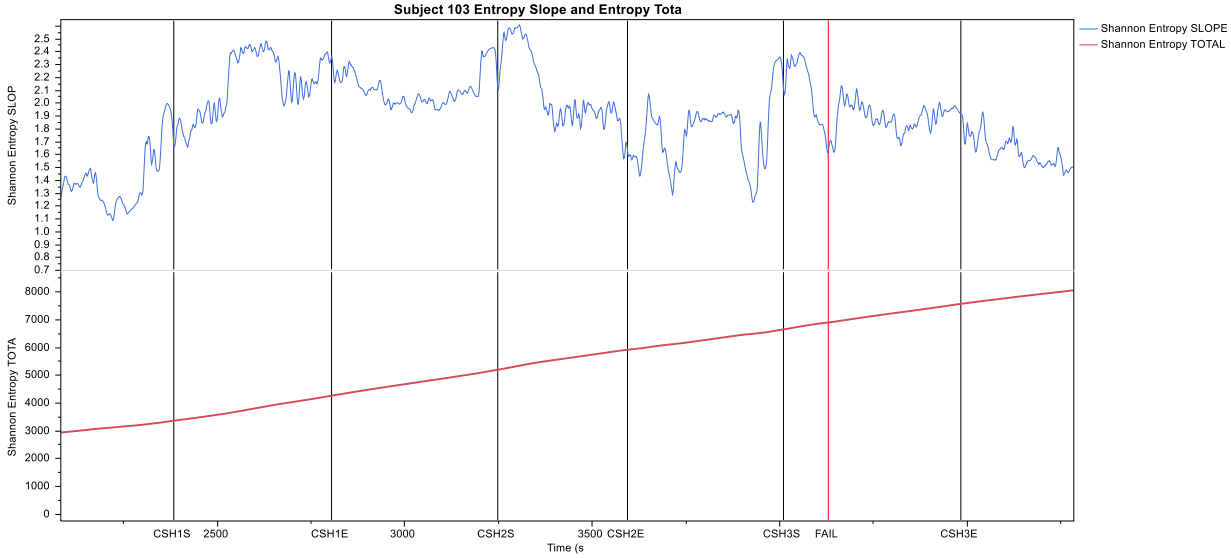

TEAM 4: SUBJ 114 RAW DATA
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s

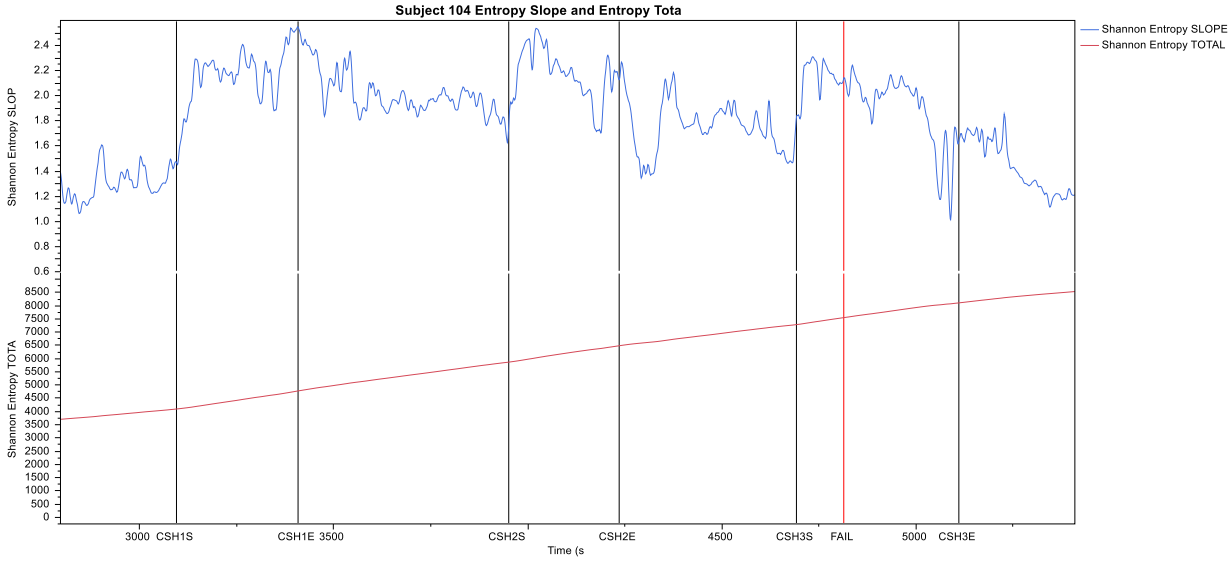

TEAM 4: SUBJ 117 RAW DATA
HR
BR
POS
ACT
TEMP K
H
B
PO
AC
TEMP
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s

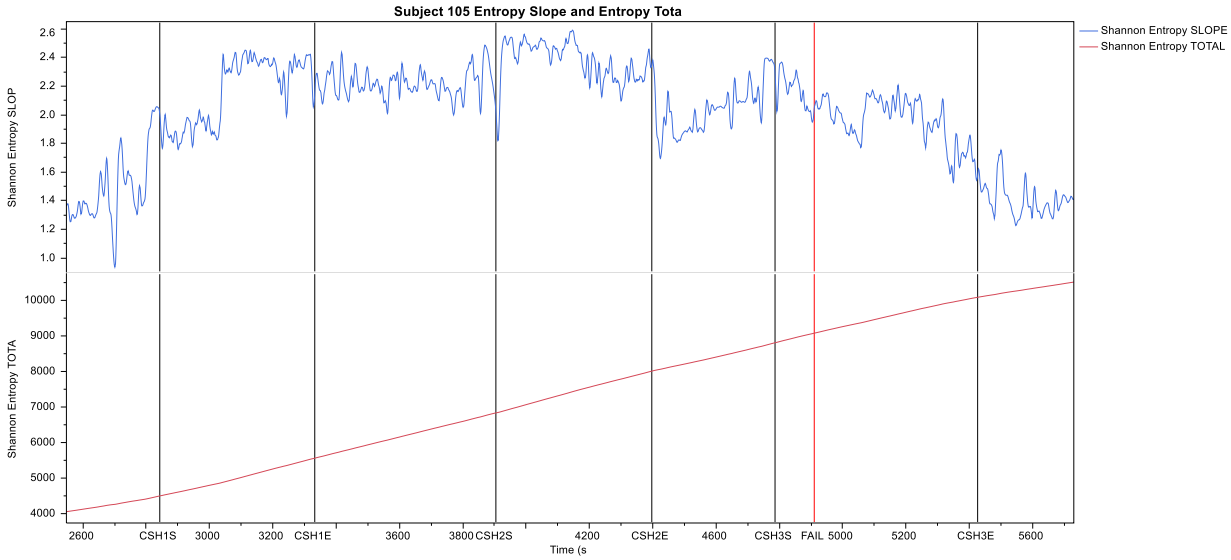
APPENDIX II:
ENTROPY CALCS INDIVIDUAL V1.0 from CSH Scenarios by subject # (101-117)

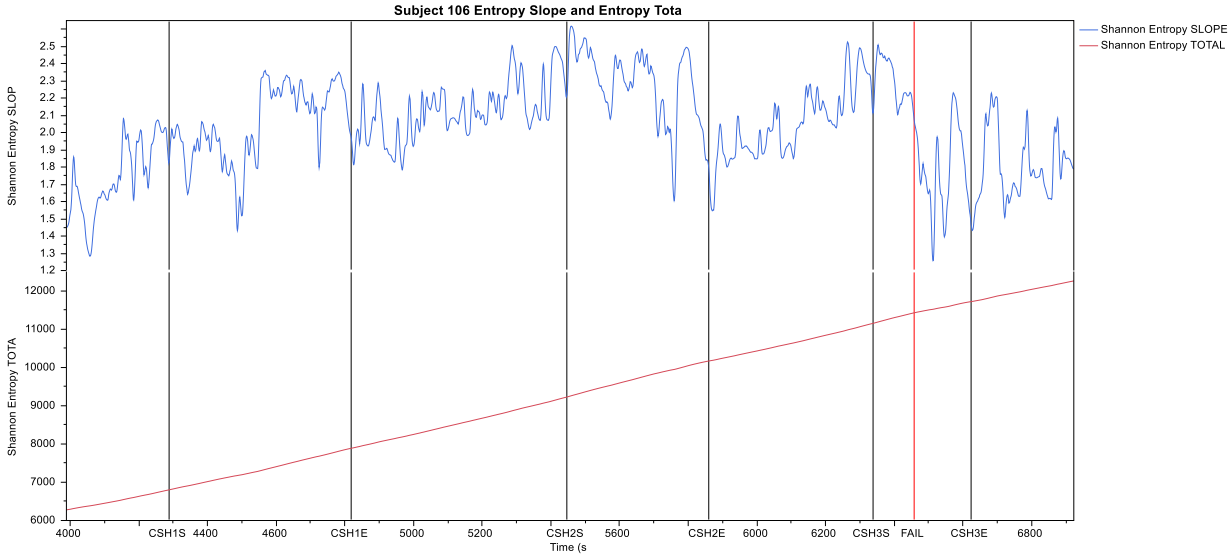


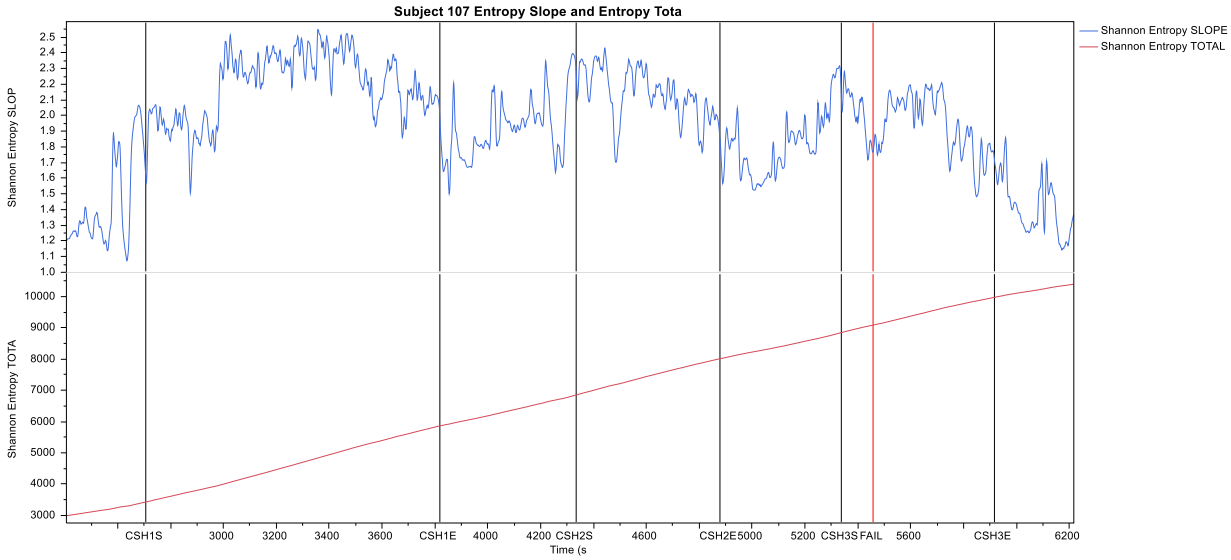


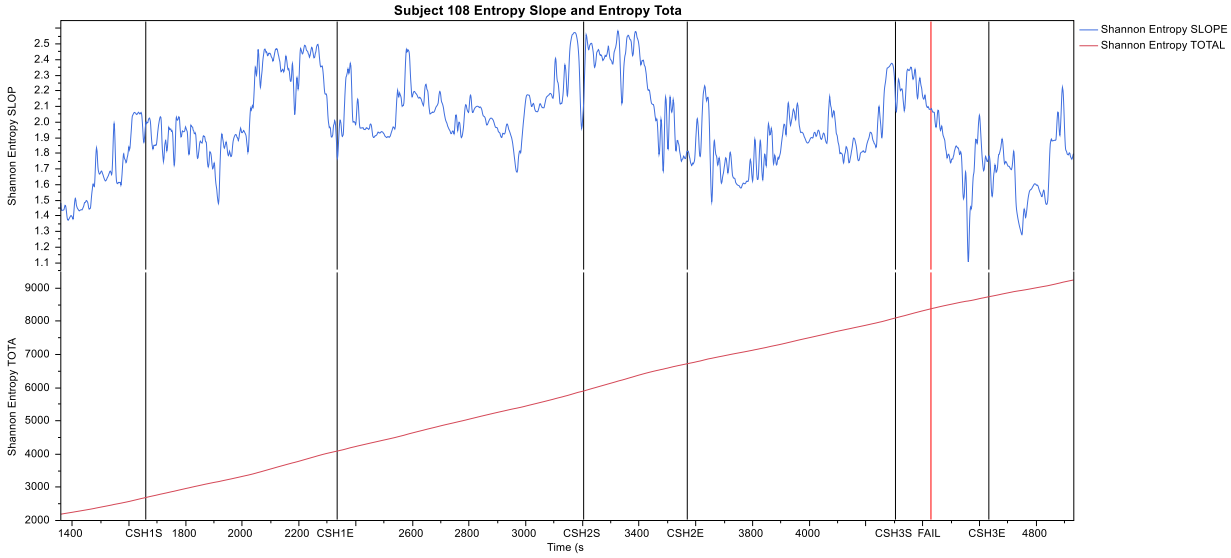

Subject 103 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
2500
CSH1E
3000
CSH2S
3500
CSH2E
CSH3S
FAIL
CSH3E
Time (s

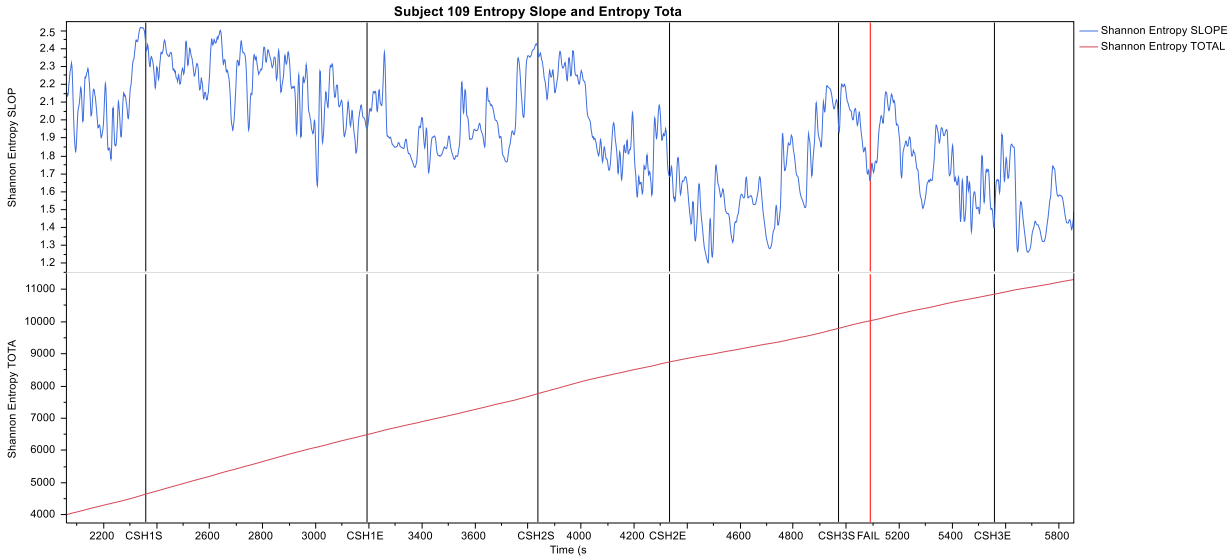

Subject 104 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Shannon Entropy SLOPE
Shannon Entropy TOTAL
3000
CSH1S
CSH1E
3500
CSH2S
CSH2E
4500
CSH3S
FAIL
5000
CSH3E
Time (s

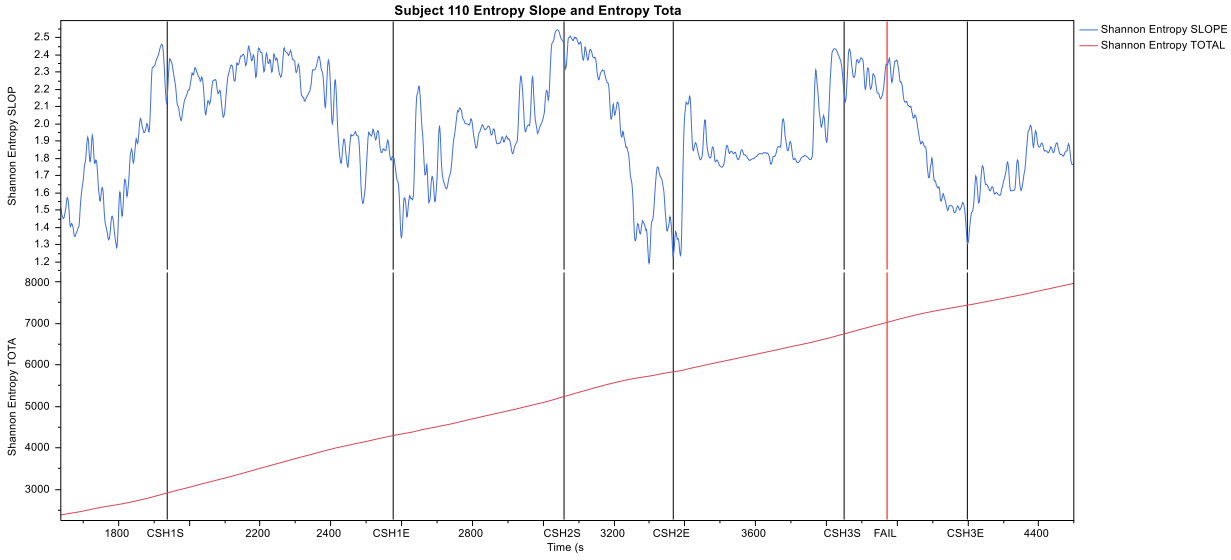

Subject 105 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E

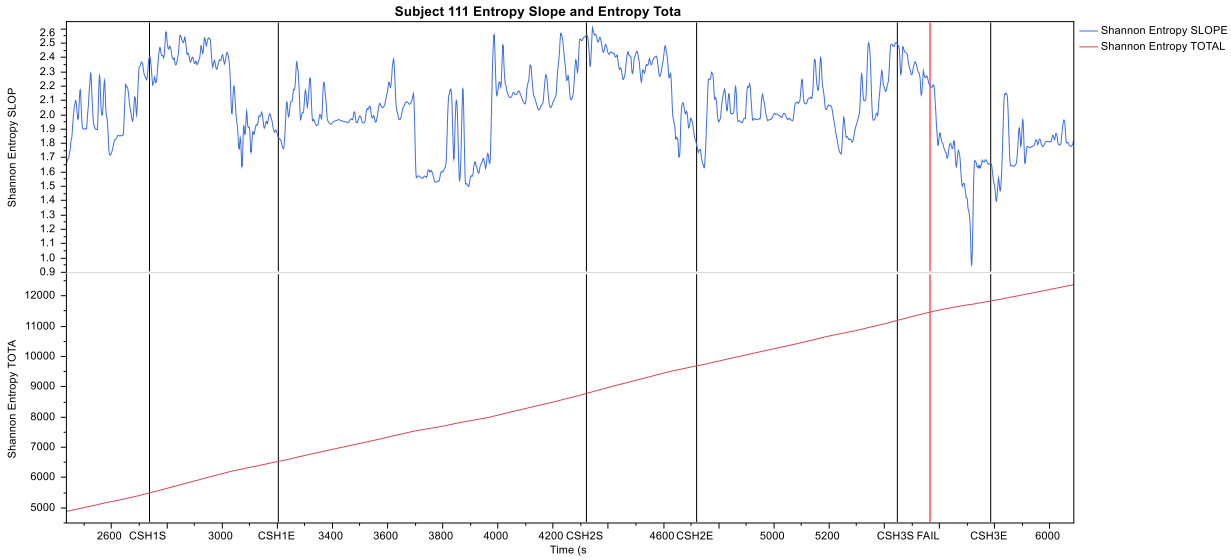

Subject 106 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E

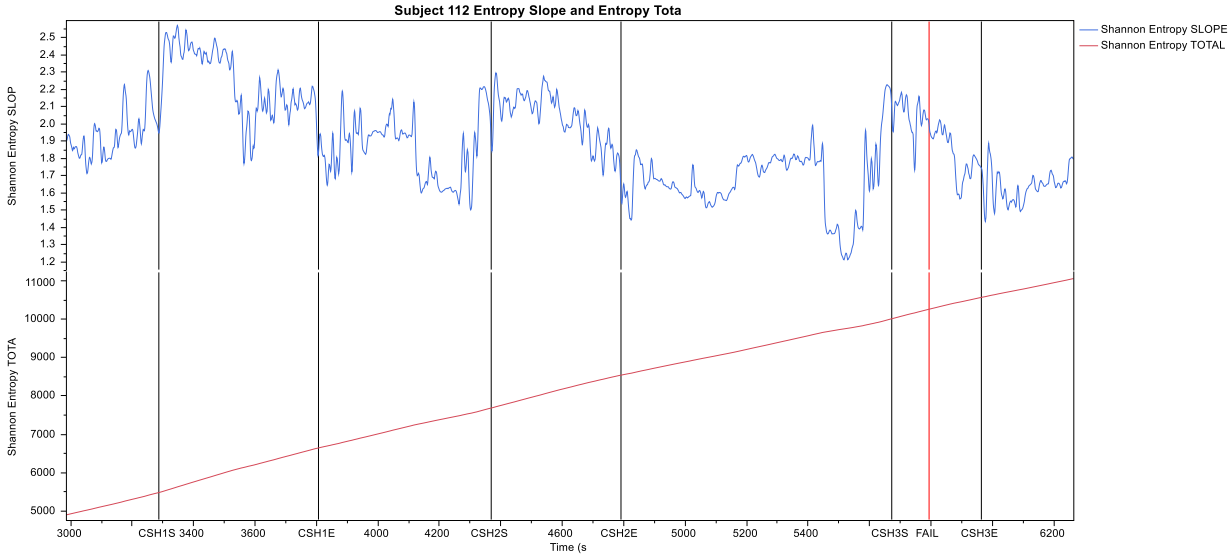

Subject 107 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E
Time (s

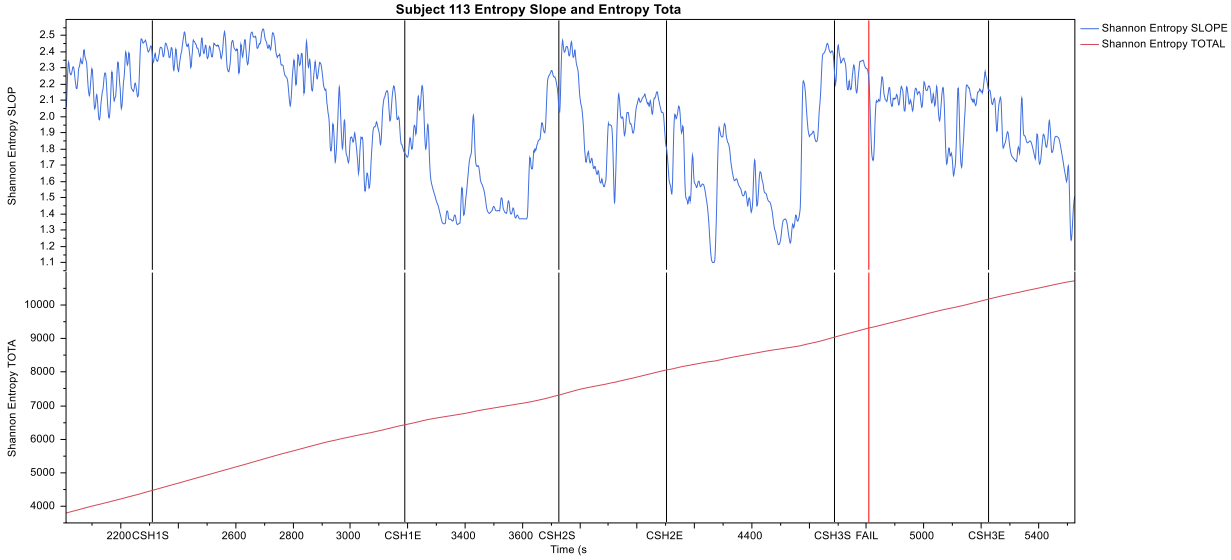

Subject 108 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E
Time (s

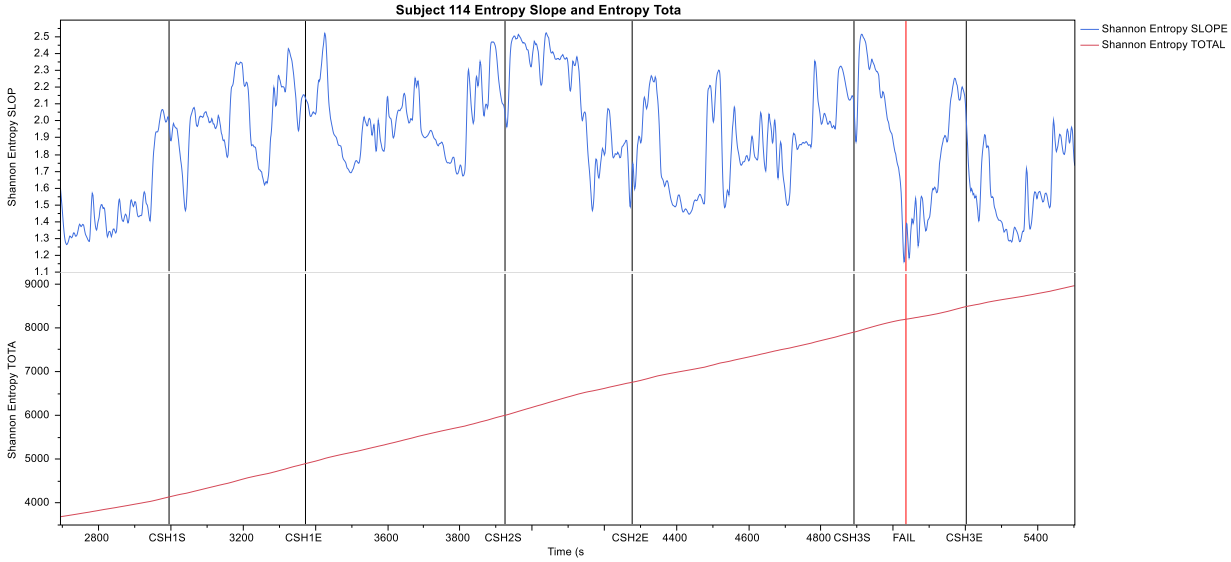

Subject 109 Entropy Slope and Entropy Tota
Shannon Entropy SLOPE
Shannon Entropy TOTAL
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
2200 CSH1S 2600 2800 3000 CSH1E 3400 3600 CSH2S 4000 4200 CSH2E 4600 4800 CSH3S FAIL 5200 5400 CSH3E 5800

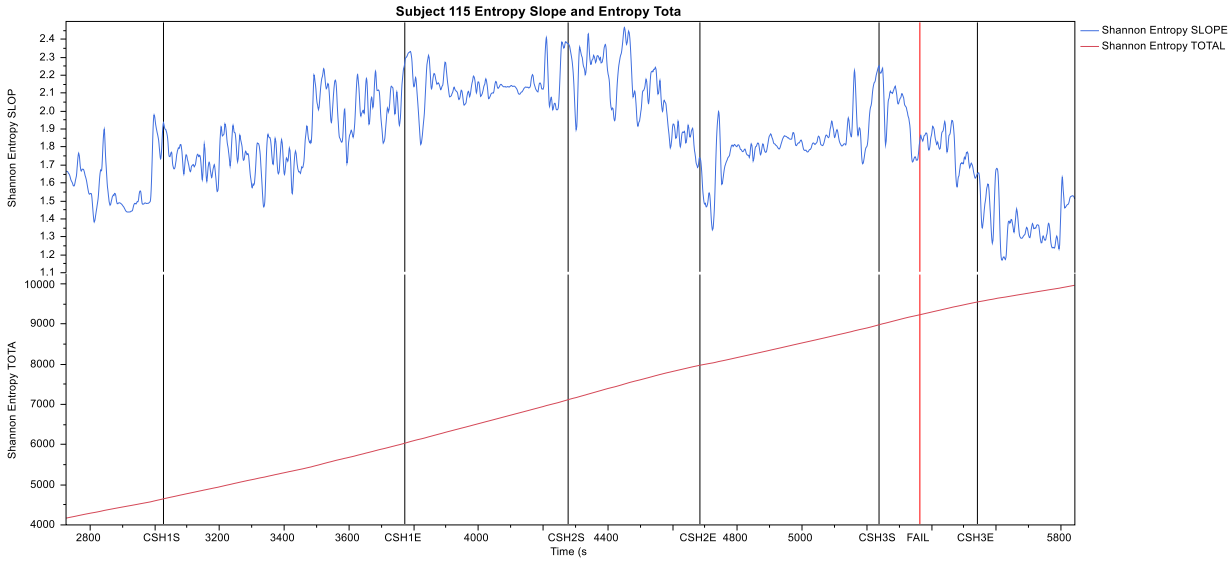

Subject 110 Entropy Slope and Entropy Tota
Shannon Entropy SLOPE
Shannon Entropy TOTAL
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
1800 CSH1S 2200 2400 CSH1E 2800 CSH2S 3200 CSH2E 3600 CSH3S FAIL CSH3E 4400

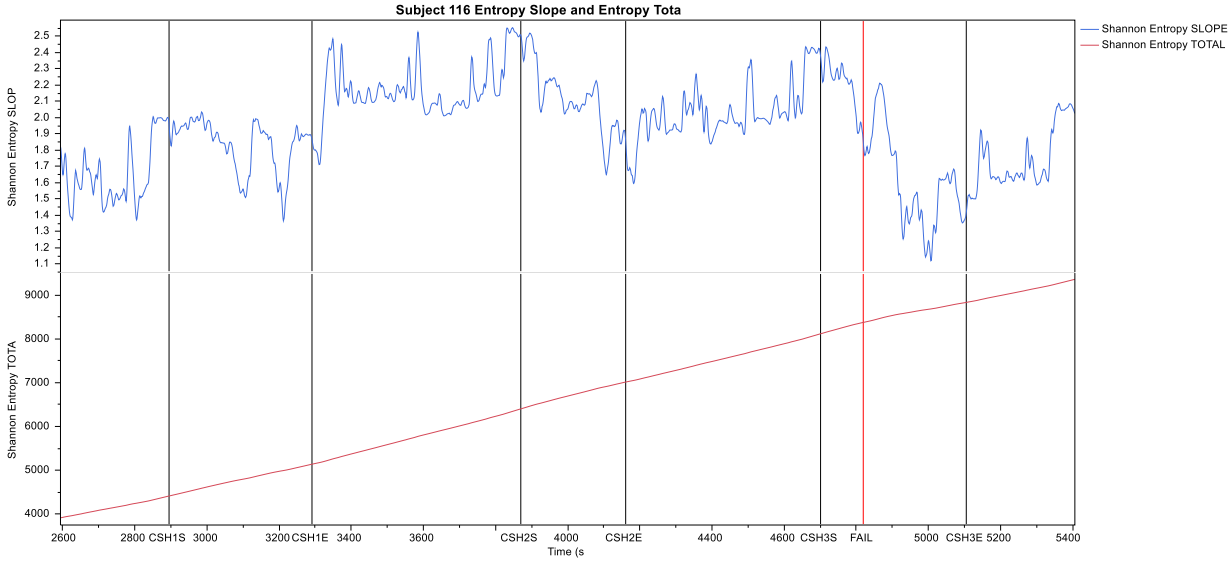

Subject 111 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
2600 CSH1S 3000 CSH1E 3400 3600 3800 4000 4200 CSH2S 4600 CSH2E 5000 5200 CSH3S FAIL CSH3E 6000

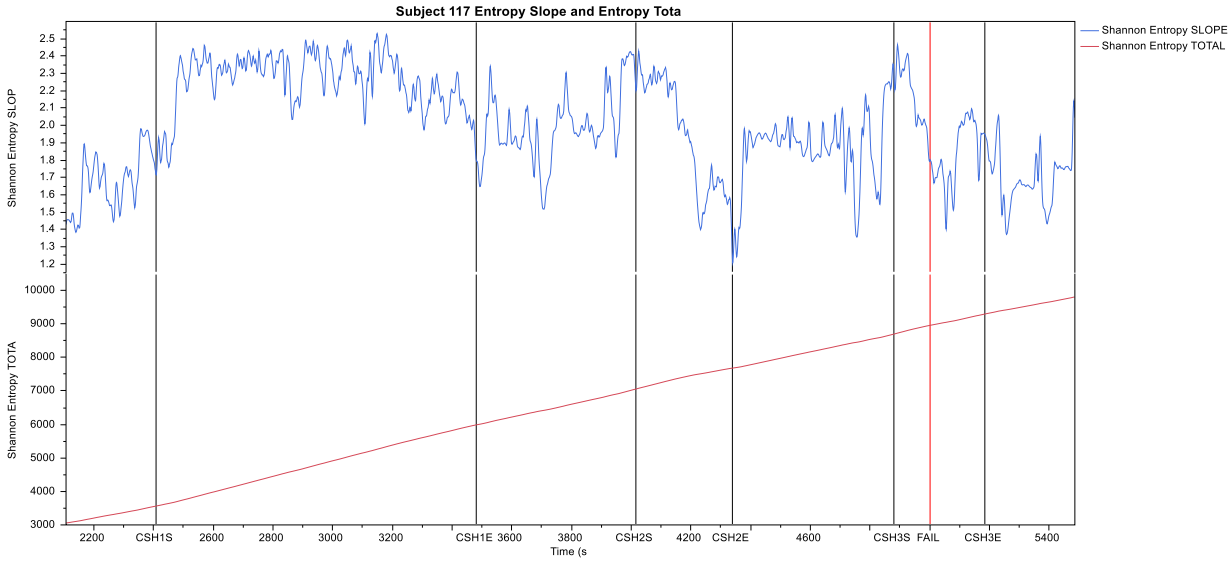

Subject 112 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
3000 CSH1S 3400 3600 CSH1E 4000 4200 CSH2S 4600 CSH2E 5000 5200 5400 CSH3S FAIL CSH3E 6200


Subject 113 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E

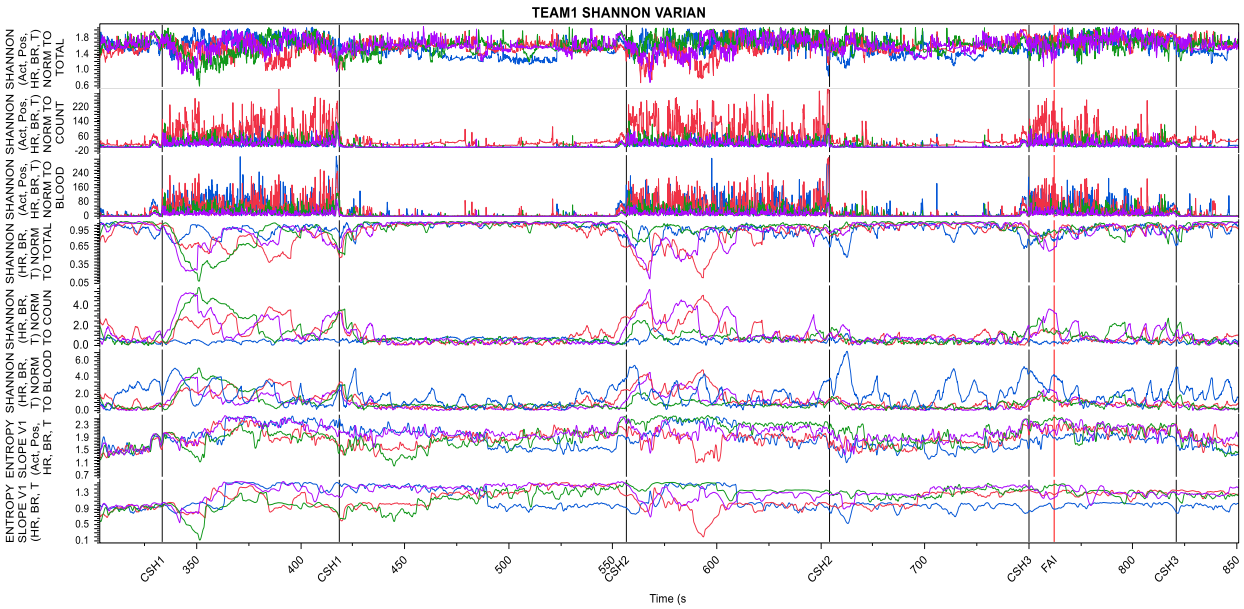

Subject 114 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E


Subject 115 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E

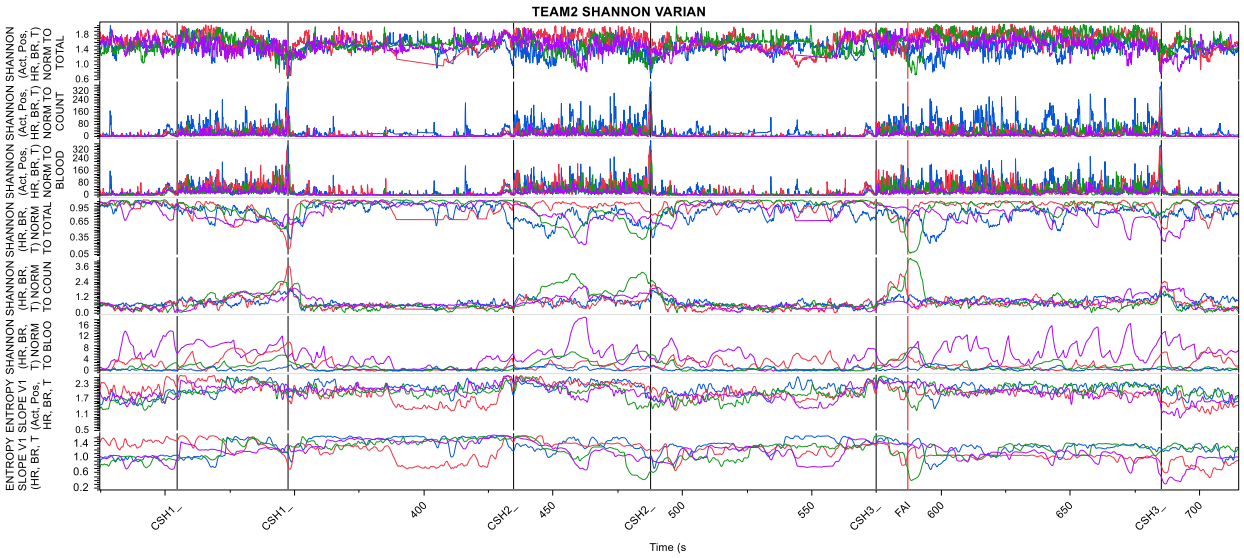

Subject 116 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E


Subject 117 Entropy Slope and Entropy Tota
Shannon Entropy SLOP
Shannon Entropy TOTA
Time (s
Shannon Entropy SLOPE
Shannon Entropy TOTAL
CSH1S
CSH1E
CSH2S
CSH2E
CSH3S
FAIL
CSH3E

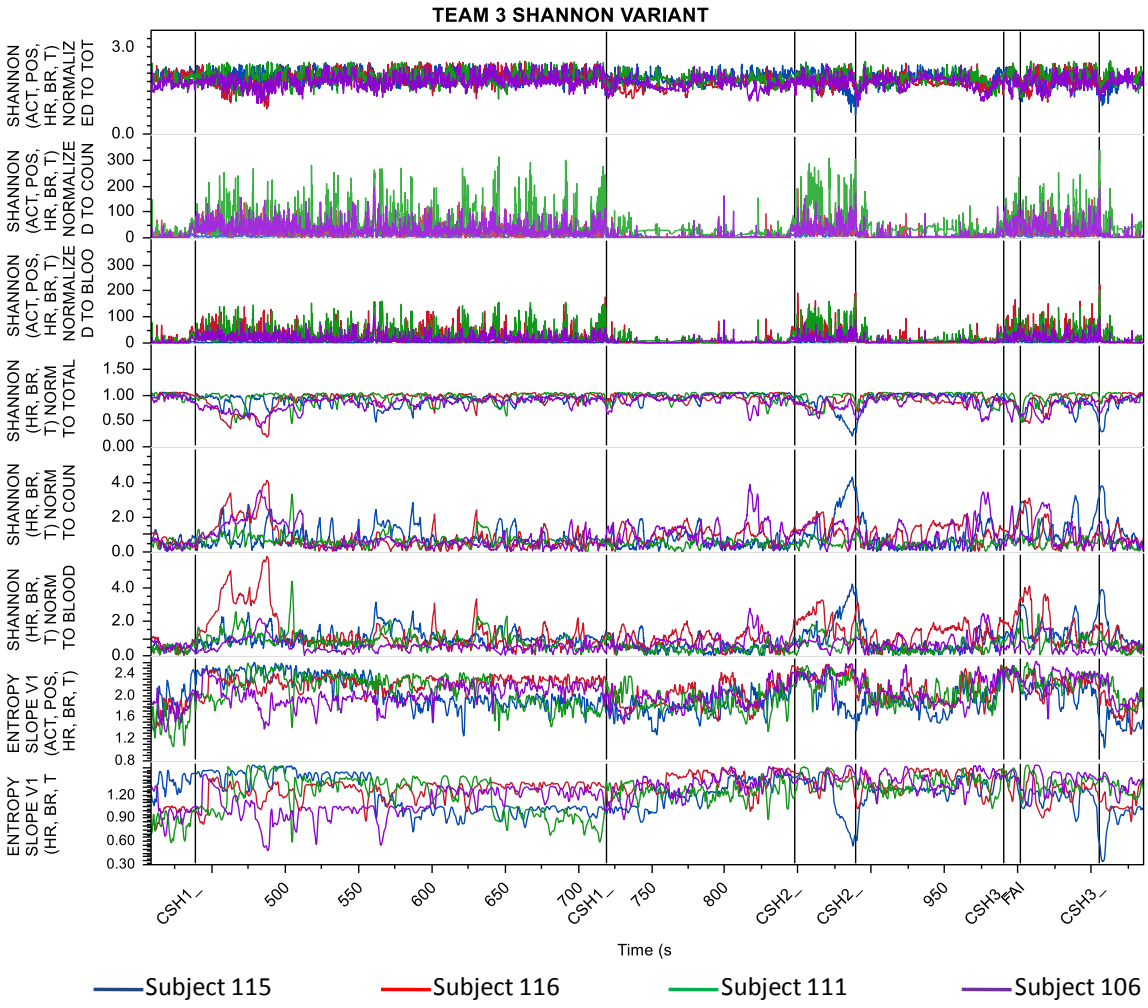
ENTROPY CALCS TEAM from CSH Scenarios by subject # (102-117)

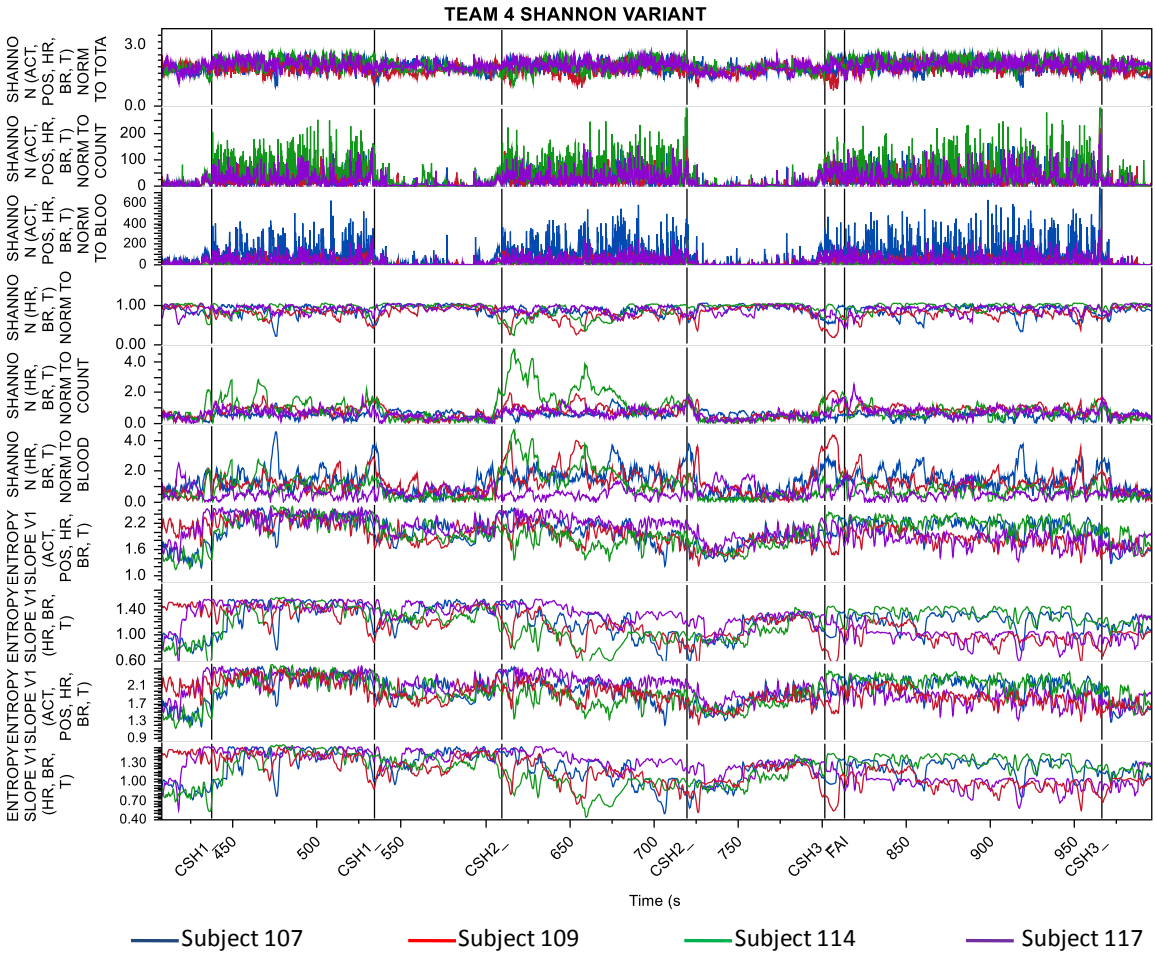


Subject 102 Subject 103 Subject 104 Subject 110



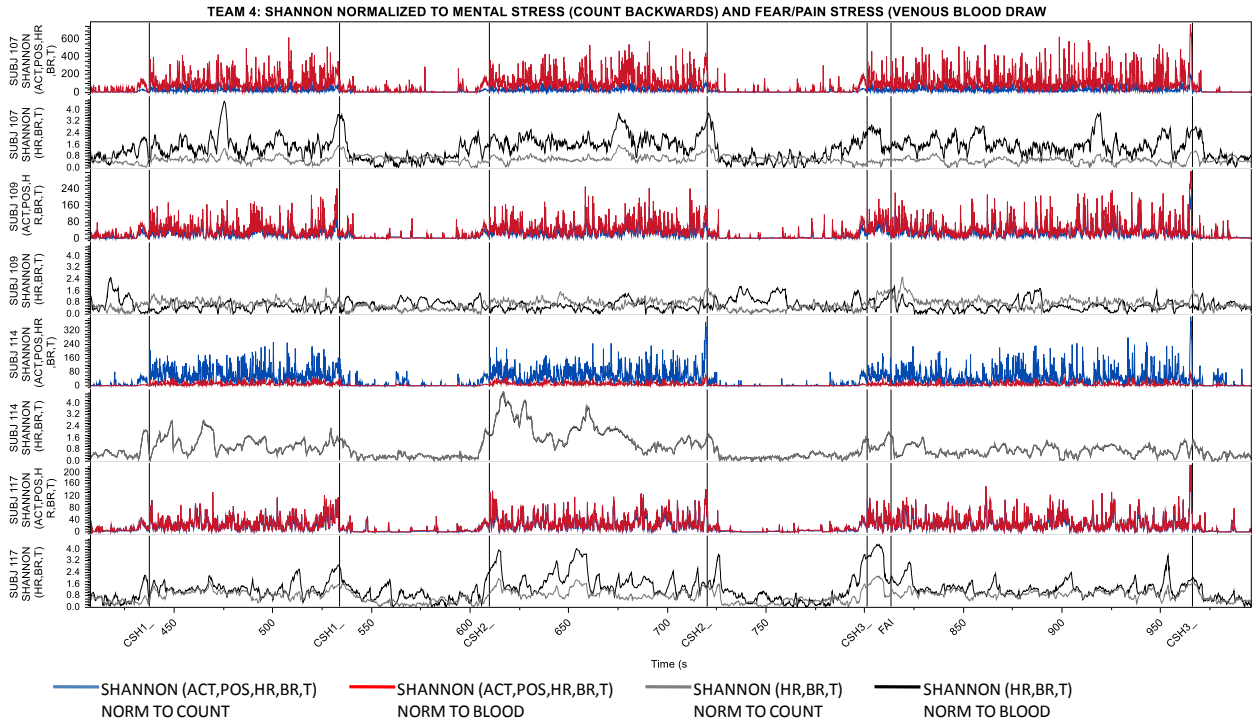
Subject 105 Subject 108 Subject 112 Subject 113


TEAM 3 SHANNON VARIANT
SHANNON (ACT, POS, HR, BR, T) NORMALIZED TO TOT
SHANNON (ACT, POS, HR, BR, T) NORMALIZED TO COUN
SHANNON (ACT, POS, HR, BR, T) NORMALIZED TO BLOO
SHANNON (HR, BR, T) NORM TO TOTAL
SHANNON (HR, BR, T) NORM TO COUN
SHANNON (HR, BR, T) NORM TO BLOOD
ENTROPY SLOPE V1 (ACT, POS, HR, BR, T)
ENTROPY SLOPE V1 (HR, BR, T
CSH1_
CSH1_
CSH2_
CSH2_
CSH3_
FAI
CSH3_
Time (s
Subject 115
Subject 116
Subject 111
Subject 106

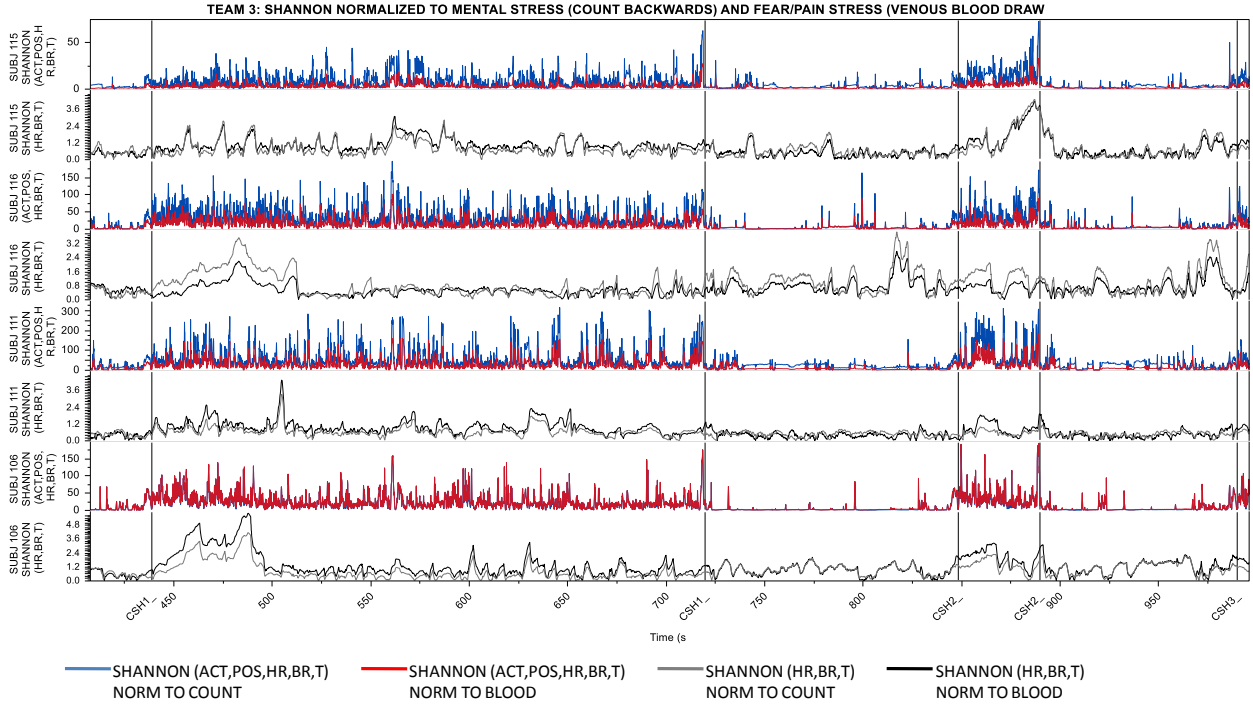

TEAM 4 SHANNON VARIANT
SHANNON (ACT, POS, HR, BR, T) NORM TO TOTA
SHANNON (ACT, POS, HR, BR, T) NORM TO COUNT
SHANNON (ACT, POS, HR, BR, T) NORM TO BLOO
SHANNON (HR, BR, T) NORM TO
SHANNON (HR, BR, T) NORM TO COUNT
SHANNON (HR, BR, T) NORM TO BLOOD
ENTROPY SLOPE V1 (ACT, POS, HR, BR, T)
ENTROPY SLOPE V1 (HR, BR, T)
ENTROPY SLOPE V1 (ACT, POS, HR, BR, T)
ENTROPY SLOPE V1 (HR, BR, T)
CSH1
CSH1_
CSH2_
CSH2_
CSH3
FAI
CSH3_
Time (s
Subject 107
Subject 109
Subject 114
Subject 117

APPENDIX 7: SHANNON FILTERED DATA NORMALIZED TO MENTAL STRESS (Counting Backwards) AND FEAR/PAIN STRESS (venous blood draw)

TEAM4: Post-survey analysis identified Subject 114 as the primary leader, with Subjects 109 and 117 serving as secondary leaders. As is demonstrated below, Subject 114 has a much higher level of mental stress, as compared to fear/pain stress.

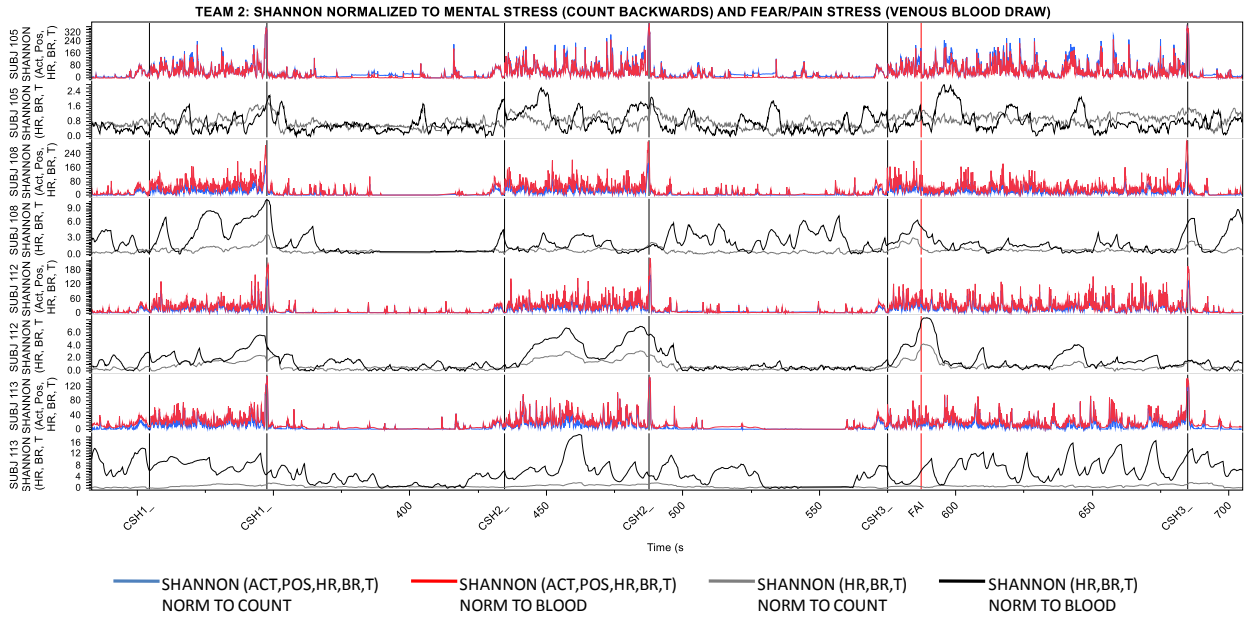


TEAM 3: Post-survey analysis identified leadership as shared between the team. In agreement with this, the graphs below indicate greater mental stress in Subjects 111, 115, and 116. Subject 106 appears to have a greater fear/pain response throughout the scenarios.



This trend does not appear perfect (as evidenced by TEAMS 1 & 2, shown below), but is worth exploring more.

TEAM 2: Post-survey analysis identified Subject 108 as the primary leader. It should be noted that Subject 105 nearly passed out during the venous blood draw (fear/pain basline), which is probably skewing his Shannon Norm to Blood (making it appear lower than it actually was) because of his extreme response to the blood draw.



TEAM 1: Post-survey analysis identified Subject 103 as the primary leader (with a minor role), and Subject 102 as the secondary leader (with a minor role). As is shown below, Subject 103 does have a higher mental stress (as compared to fear/pain stress), but Subject 102 does not. Subject 110 also has a higher mental stress as compared (as compared to fear/pain stress), but was not identified as a leader.